The Radar

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Meteorologist Brendan Schaper

NWS Nashville, TN


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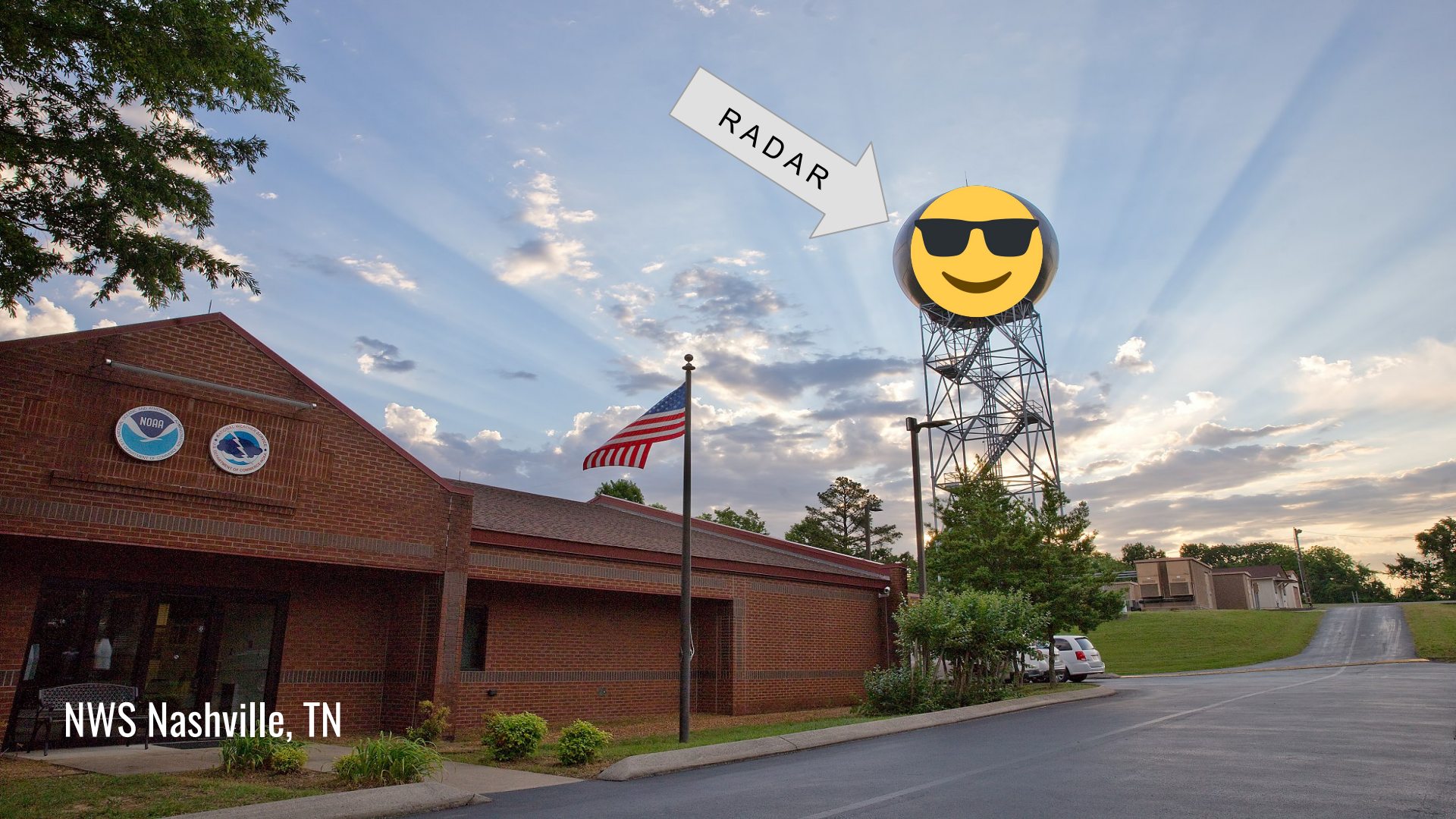
Weather101


RADAR
NOAA
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In this lesson

- Background and History
  - What is radar?
  - How does it work?
  - Limitations and advantages
  - Advancements in radar
- Radar products and applications
  - Base (Z, V, SW) and Dual-Polarization

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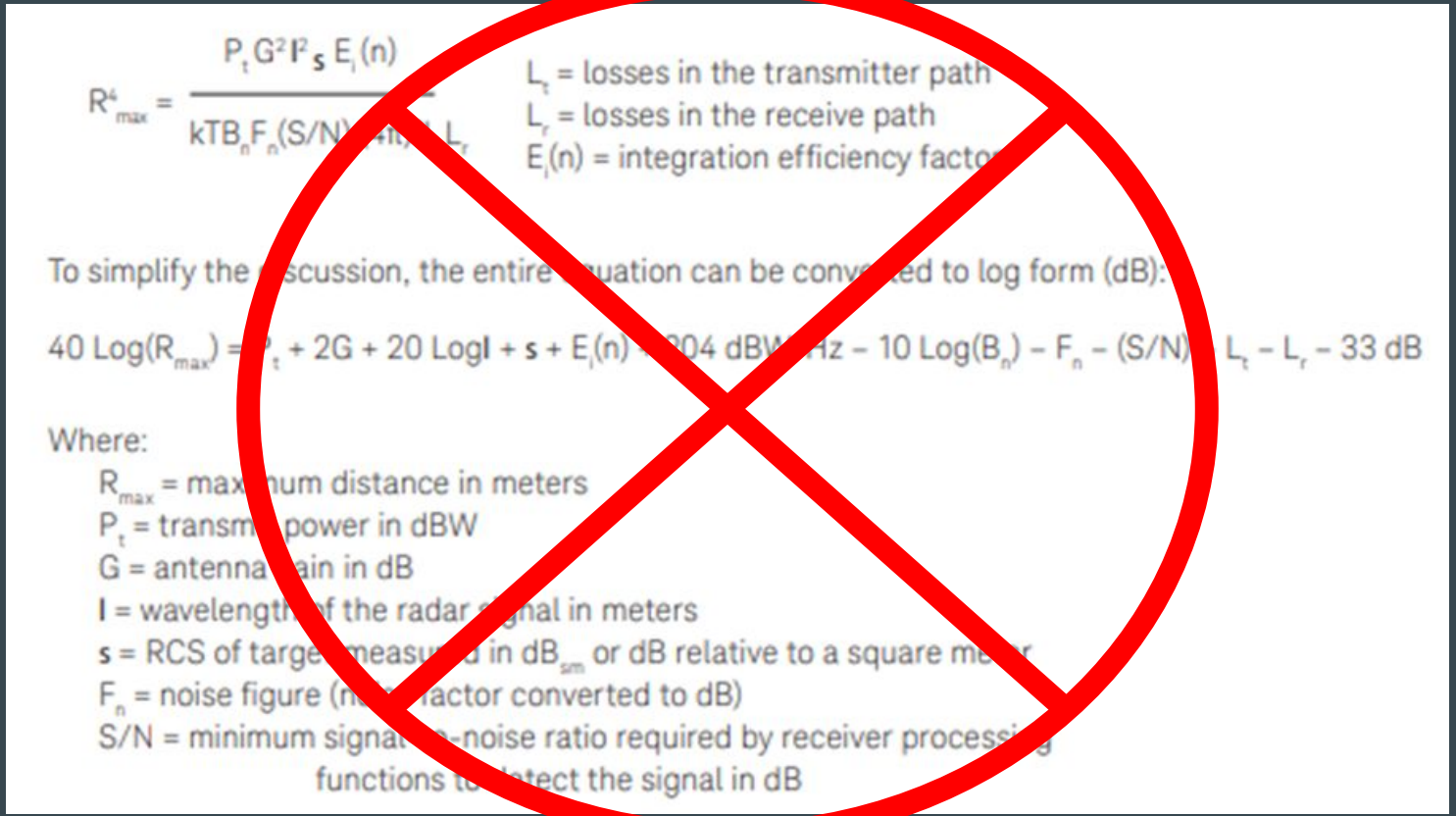

First, we must derive the radar equation...

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War...What Is It Good For?

- Radar began as a way to detect enemy aircraft and ships
- During World War II, operators noticed “weather noise”
- WSR-1 entered service in 1947
- Since then...

  WSR-1A, WSR-3, WSR-4, WSR-57, WSR-74, WSR-88D*

* In operation today.

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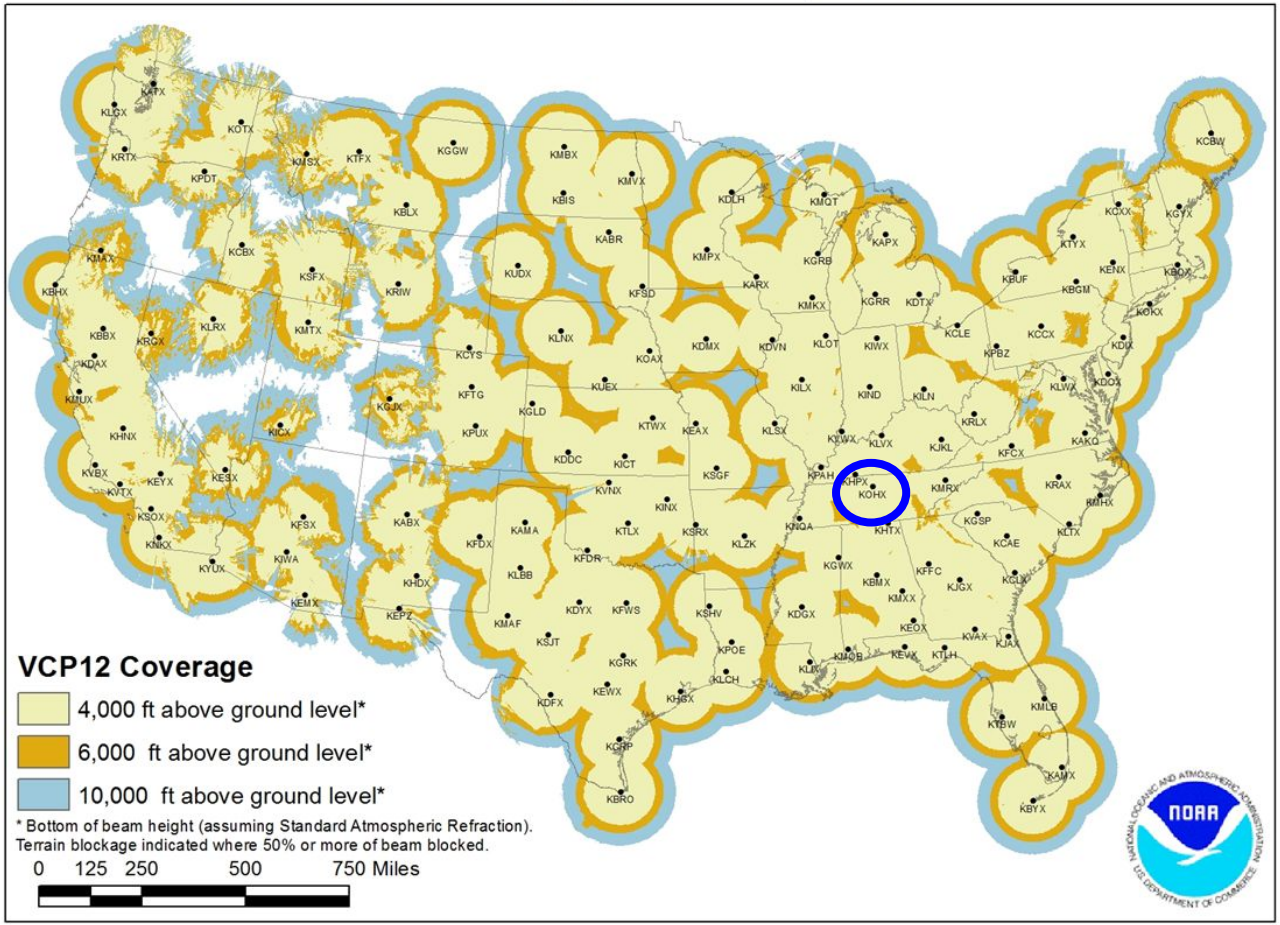
NEXRAD Coverage Below 10,000 Feet AGL



- Radars each have a 4-letter callsign
- Nashville's radar is KOHX

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How Radar Works

- Antenna dish spins 360 degrees and can tilt up to 19.5 degrees
- Brief pulse of energy is sent
    - Pulses used to display target distance/range from the antenna
- Radar “listens” for energy to travel back from a target

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Question Time

Limitations of Radar

- Refraction of radar beam
- Curvature of Earth's surface
- "Cone of silence" and proximity to radar
- Beam spreading and storm location (more ambiguity)

Limitations of Radar

- **Refraction of radar beam**
- Curvature of Earth's surface
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Refraction of Radar Beam

- Refraction
  - As the radar beam propagates through the atmosphere, the top of the beam travels faster than the bottom. This causes bending or refraction of the beam.
- Causes may include:
  - Pressure
  - Temperature
  - Moisture

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Causes of Radar Beam Refraction

- Pressure (main cause of refraction)
  - Decreases with height, causing beam to bend downward
- Temperature
  - Generally decreases with height, causing beam to bend upward. Higher lapse rates increase upward bending.
    - **A temperature inversion will cause the beam to bend downward.*
- Moisture
  - Typically, vapor pressure decreases with height, causing beam to bend downward. A more rapid decrease in vapor pressure increases downward bending (and vice versa).
    - **Increases in vapor pressure with height will cause beam to bend upward.*

https://www.weather.gov/jetstream/beam_max

Normal refraction

Beam bends
more than normal

Beam bends **less than**
normal

Beam **really bends**
more than normal

Limitations of Radar

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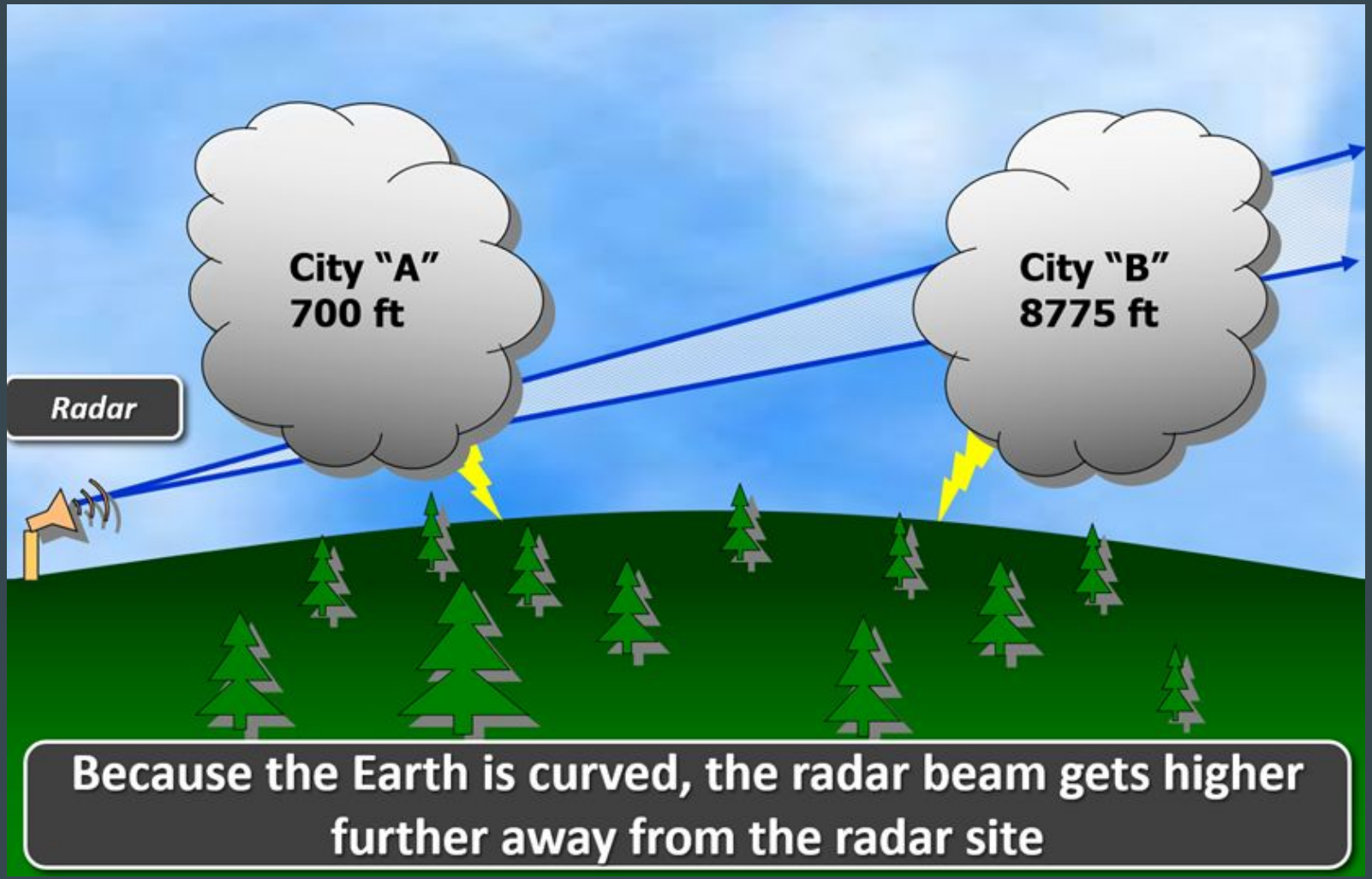
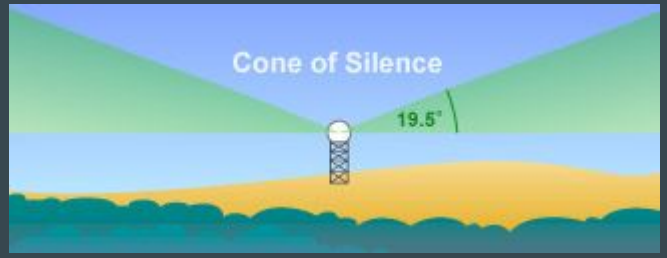

City "A"
700 ft
City "B"
8775 ft
Radar
Because the Earth is curved, the radar beam gets higher further away from the radar site

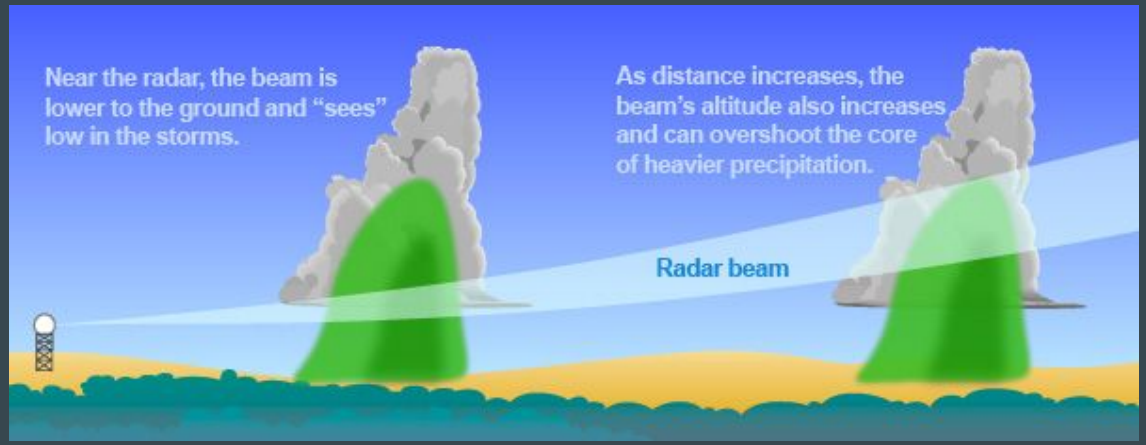
Limitations of Radar

- Refraction of radar beam
- Curvature of Earth's surface
- **"Cone of silence" and proximity to radar**
- Beam spreading and storm location (more ambiguity)

Cone of Silence and Proximity to Radar

- “Cone of silence” is the area where radar is limited in its ability to scan directly overhead.
- Cone of silence radius: ~ 1 nautical mile
- Storms closer to the radar are being scanned at lower levels than storms farther away





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CONE OF SILENCE

19.5 degree tilt (highest radar tilt)

Cone of Silence Demonstration

Question Time

Limitations of Radar

- Refraction of radar beam
- Curvature of Earth's surface
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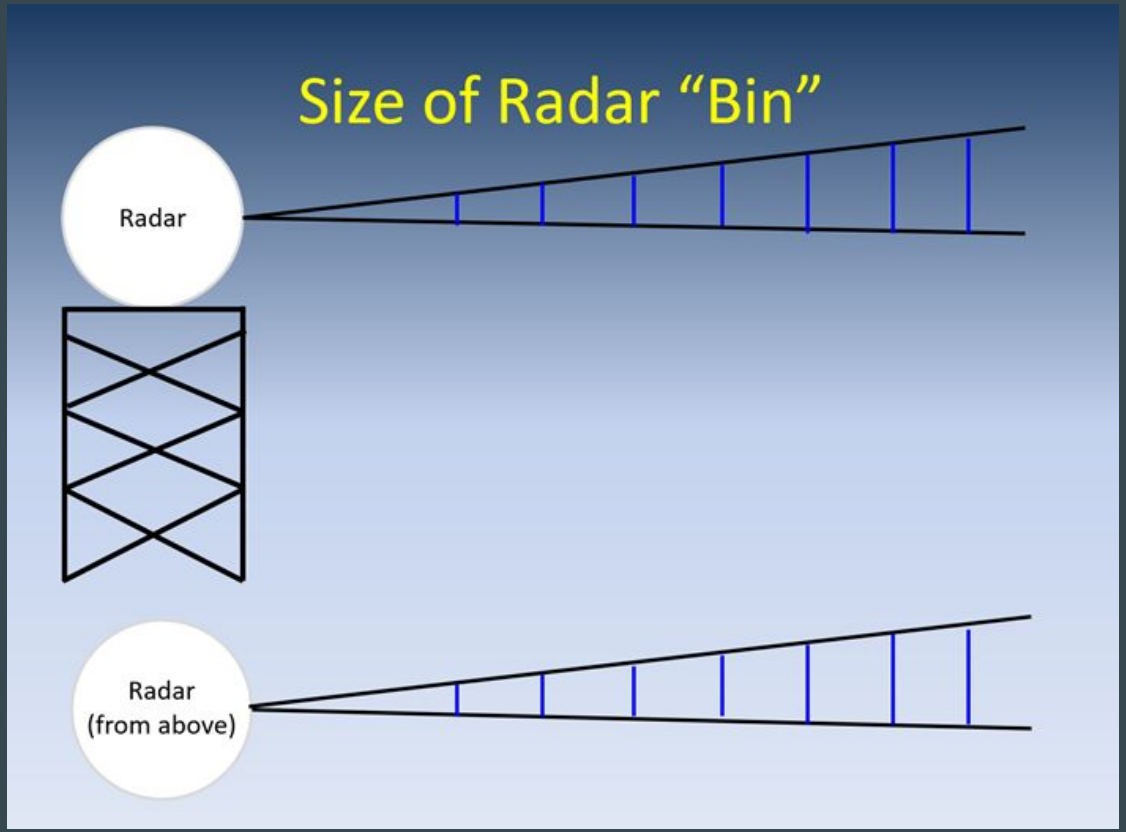
- **Beam spreading and storm location (more ambiguity)**



Beam Spreading

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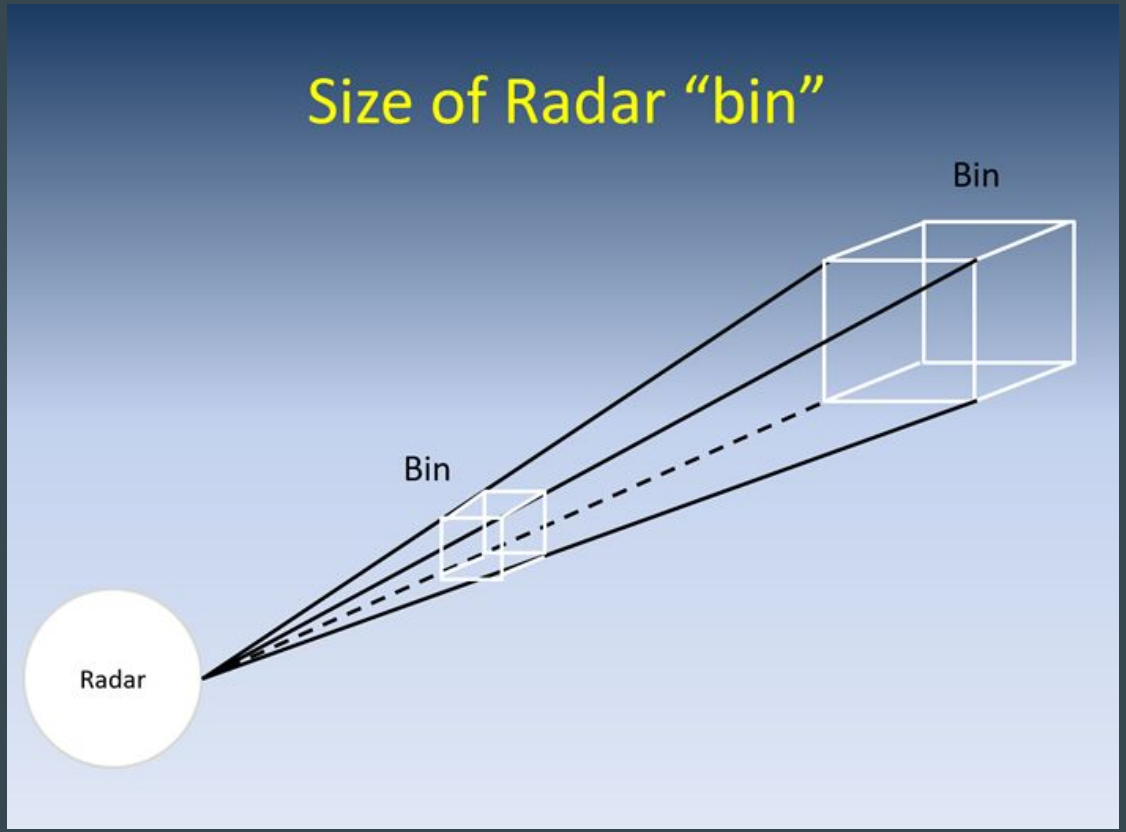

Beam Spreading

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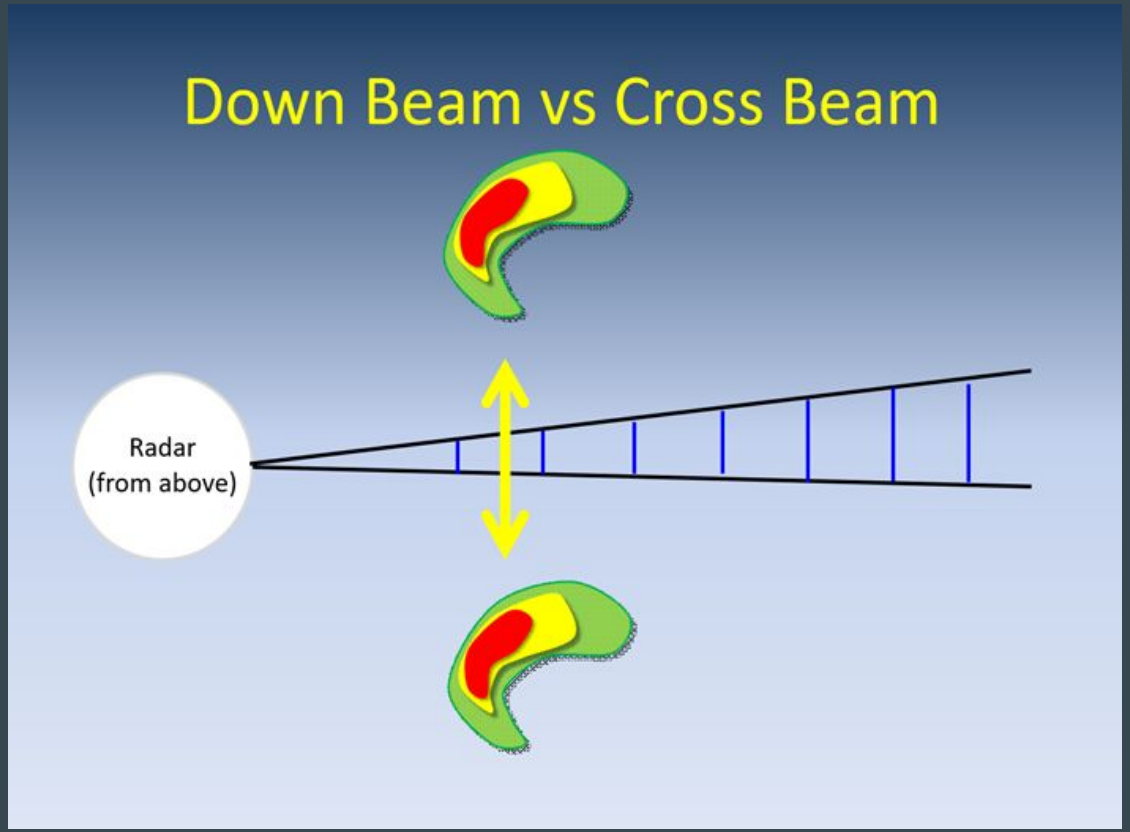

Storm Location in relation to radar beam

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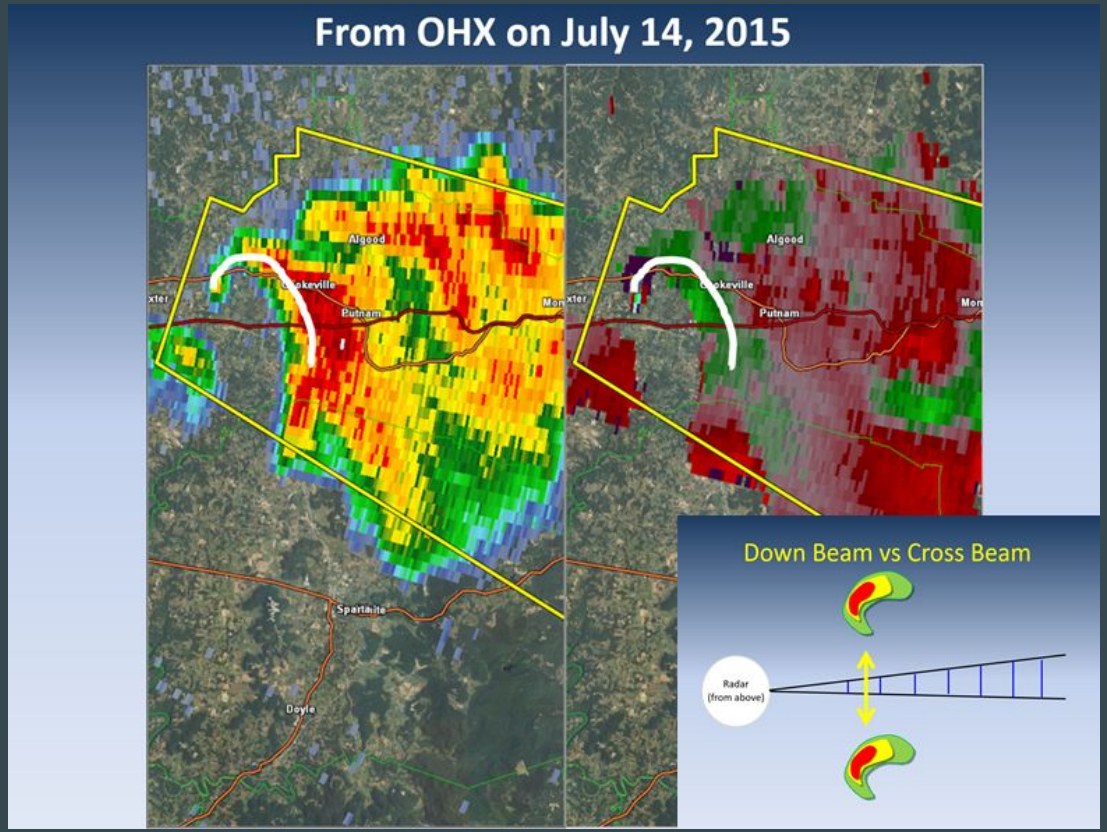

Storm that is cross beam

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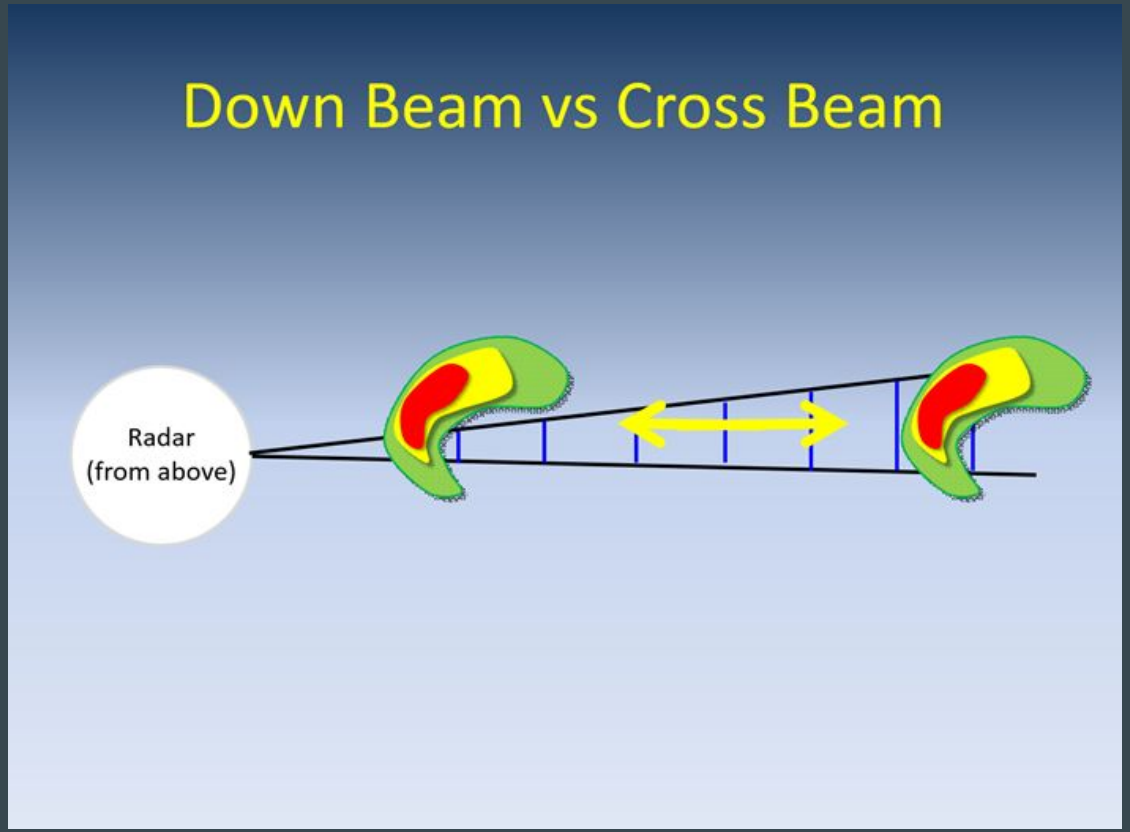

Storm Location in relation to radar beam

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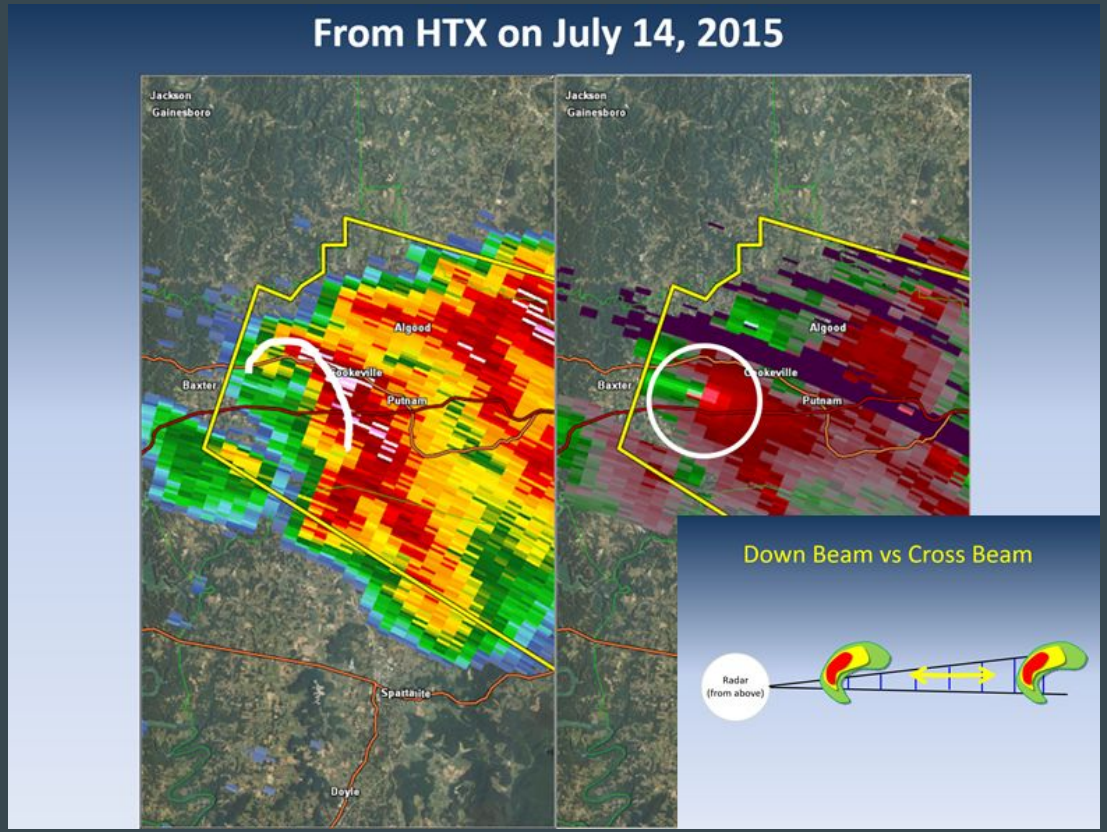

Storm that is down beam

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Conventional v. Dual-Pol Radar

- Conventional: standard horizontal pulse
- Detects targets, “listens” for energy to return

versus

- Dual-pol: upgrades completed in 2013
- Standard horizontal pulse *plus* a vertical pulse
- Hail detection, raindrop size, improved rainfall estimates, non-meteorological targets
- Detection of chaff, debris, and melting layer (CC)

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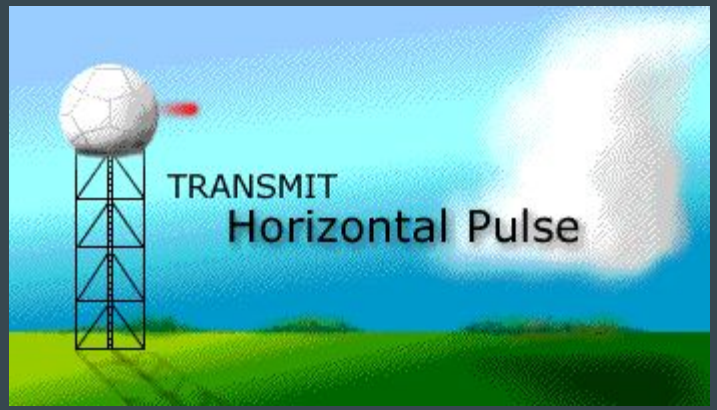
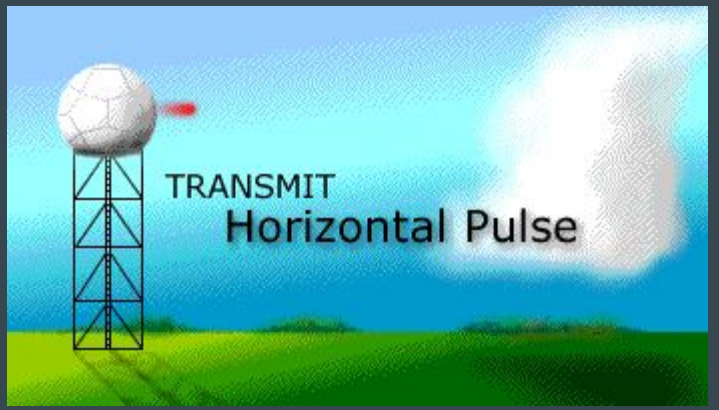


Conventional radar

VS



Dual-pol radar

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Lowest to highest elevation
19.5°
15.6°
12.5°
10.0°
8.0°
6.4°
5.1°
4.0°
3.1°
2.4°
1.8°
1.3°
0.9°
0.5°
Radar slices or tilts
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Radar Products

- Conventional
  - Reflectivity
  - Velocity
  - Spectrum width
- Dual-pol
  - Reflectivity
  - Velocity
  - Spectrum width

  ...plus

  - Differential reflectivity
  - Correlation coefficient
  - Specific differential phase

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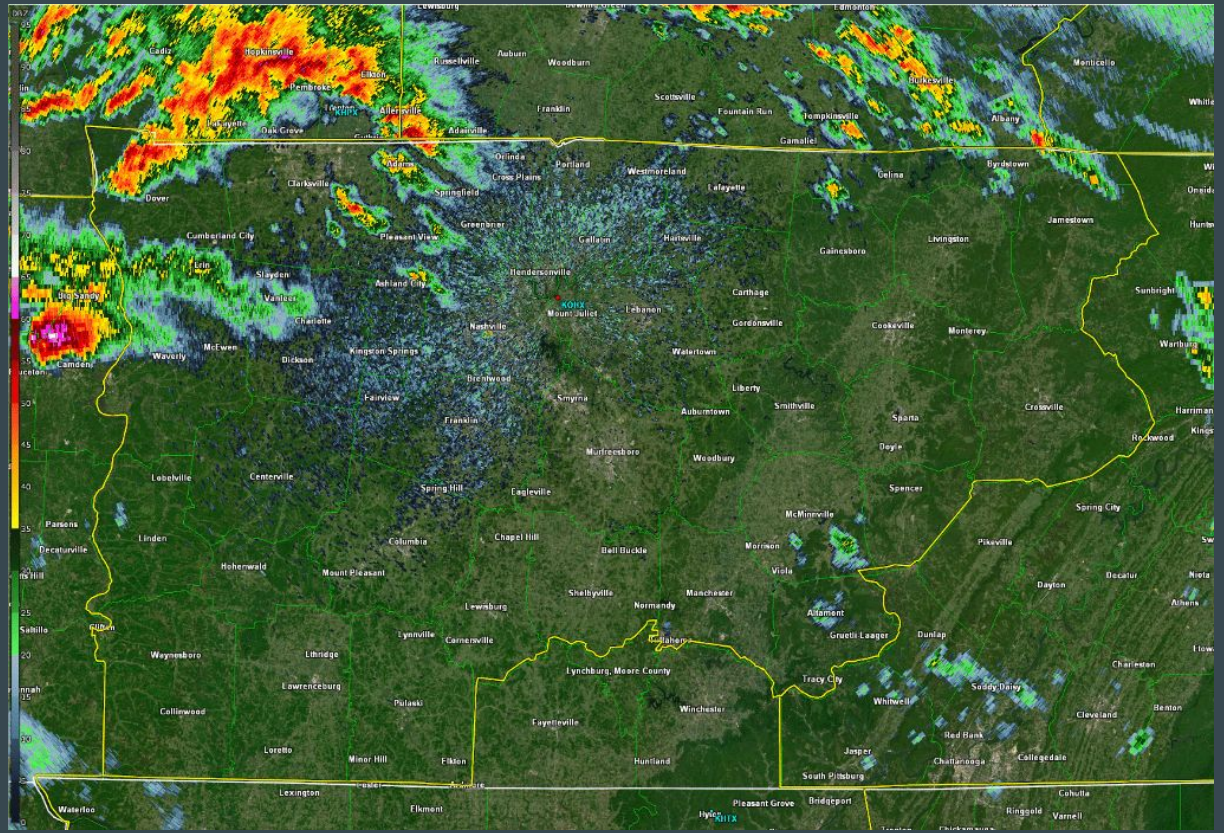

Reflectivity - March 3, 2020

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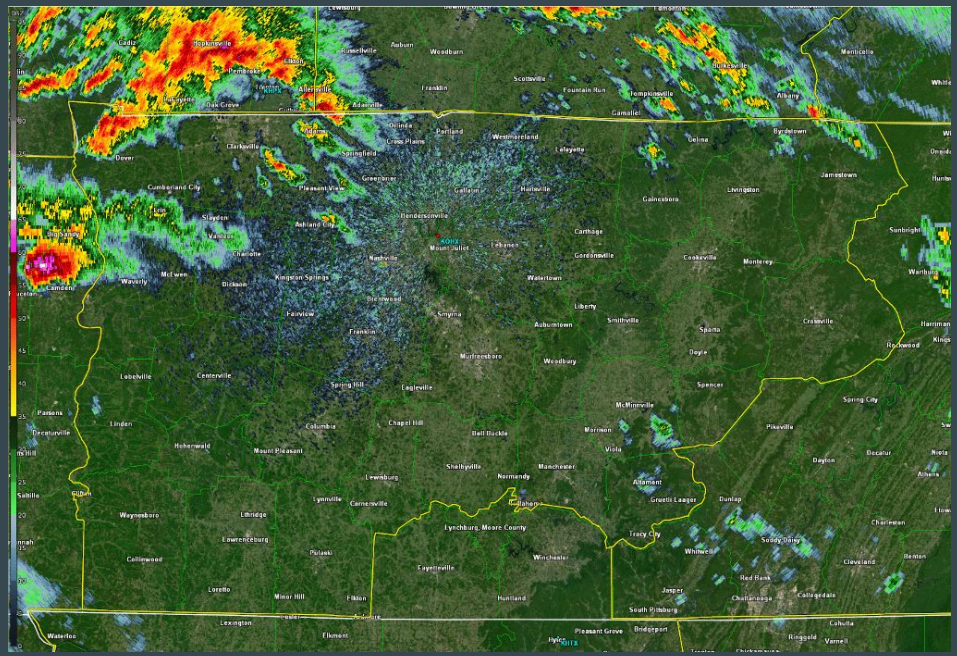
Reflectivity (Z)

- Estimated returned power converted to an equivalent value
  - Measured in dBZ
- Most commonly used/seen product
  - Helps to identify precipitation and some non-meteorological targets



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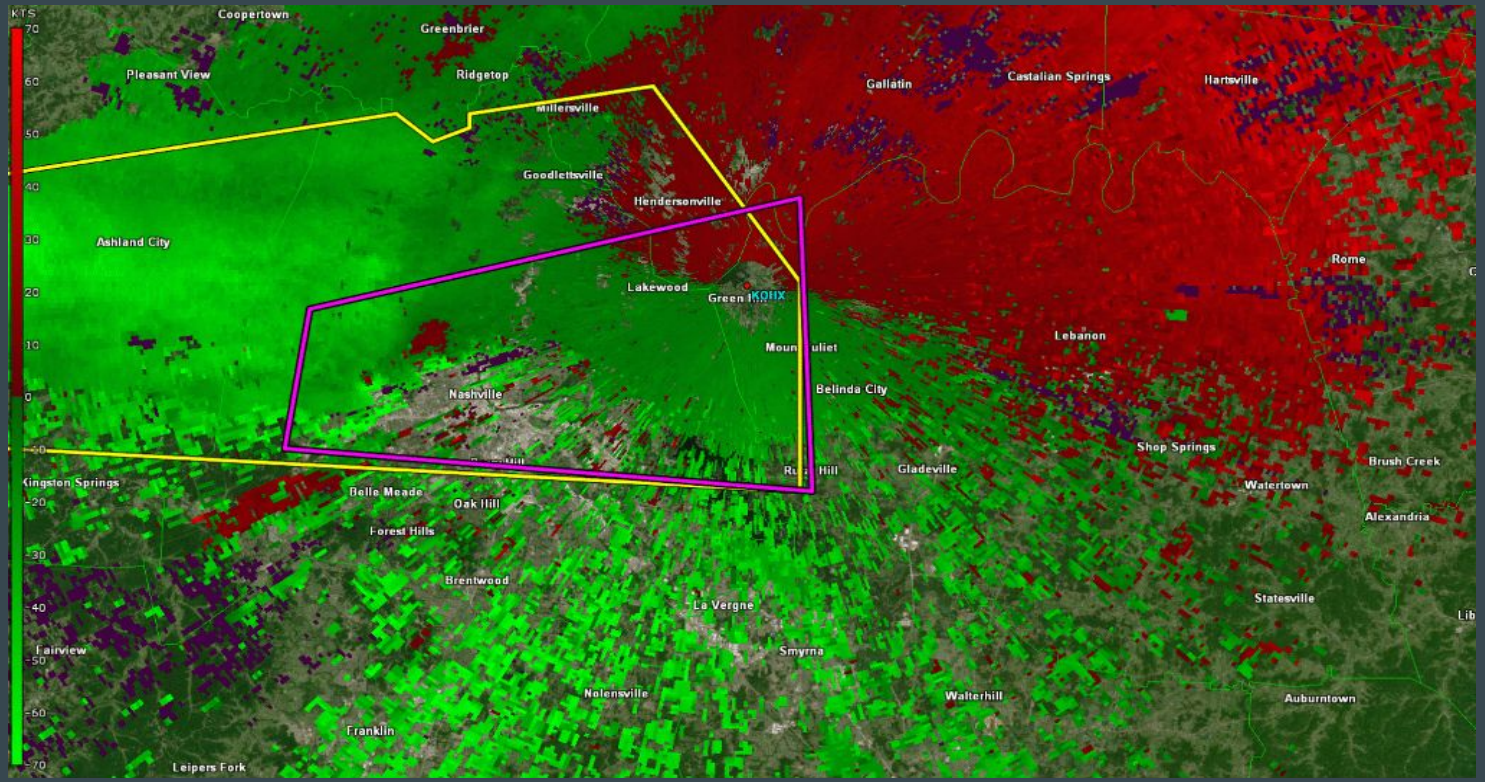

Velocity - March 3, 2020

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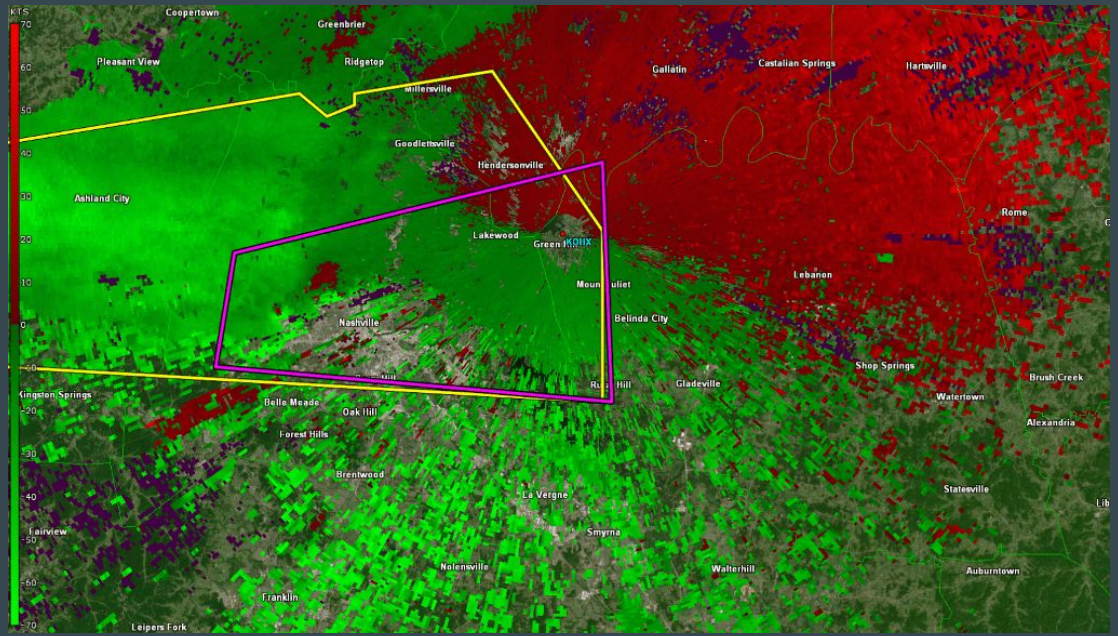
Velocity (V)

- Motion of a target detected, either toward or away from the radar
    - Measured in knots (kts)
- Commonly used to detect damaging winds and tornadoes

**Need to enough targets for accurate reading*



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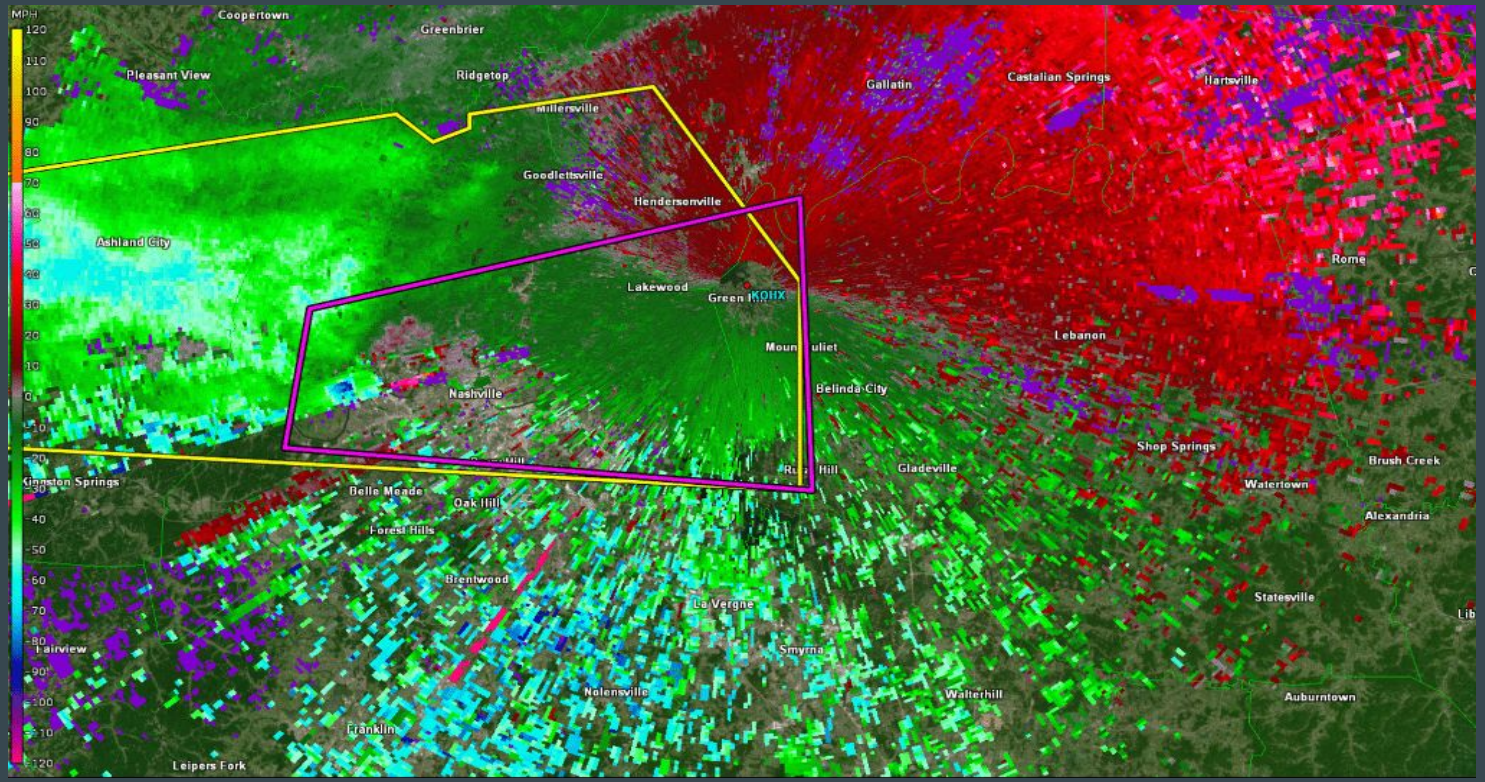

Storm-relative velocity - March 3, 2020

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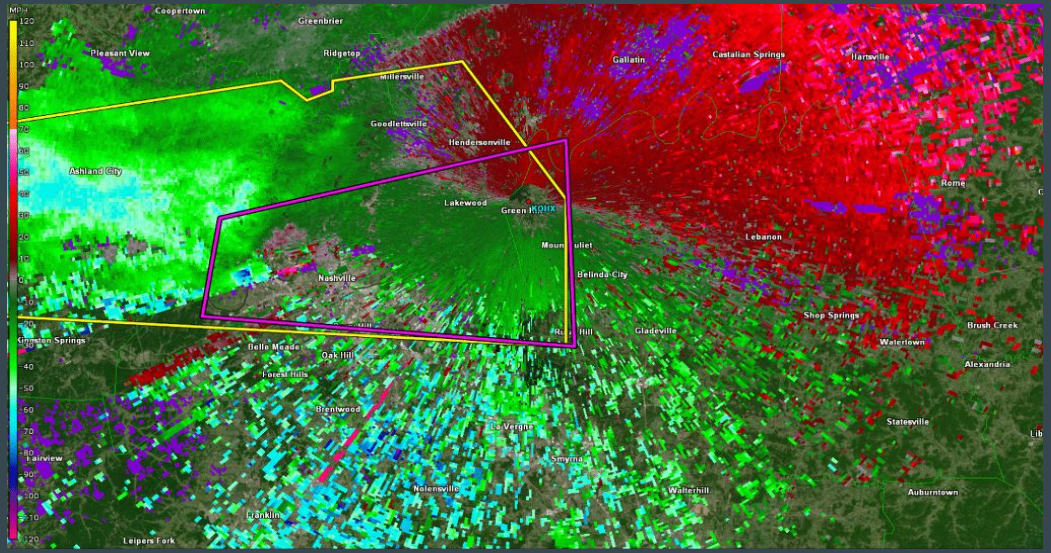
Storm-Relative Velocity (SRM)

- Motion of a storm subtracted out to help better identify rotation
  - Measured in knots (kts), converted to miles per hour (mph)
- Storm motion (speed and direction) can be manually adjusted in some radar software

**Need to enough targets for accurate reading*



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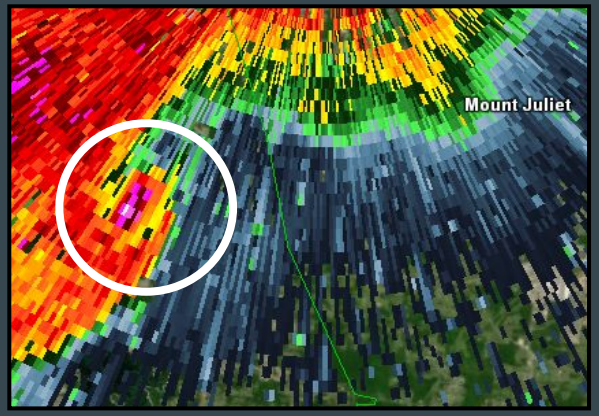

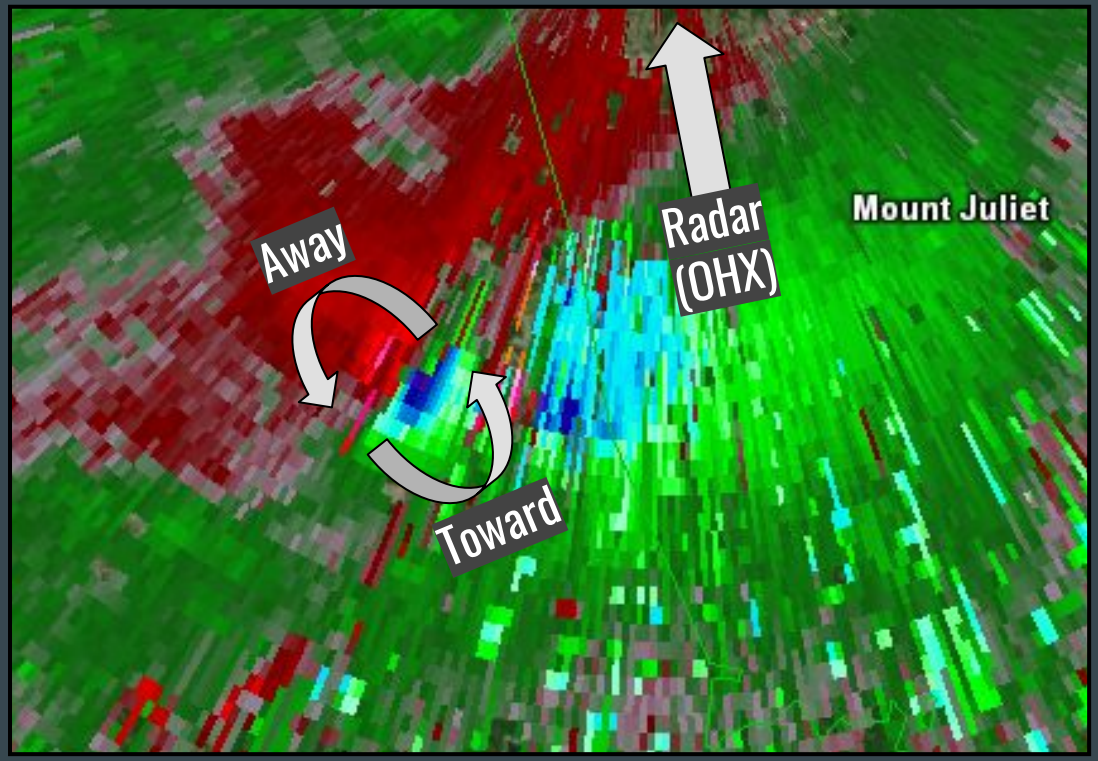

- Look for gate-to-gate winds (typically shades of red and green on velocity images)
    - Strong winds, adjacent on radar, usually indicate rotation

**Reflectivity must be co-located with velocity*

Identifying Rotation

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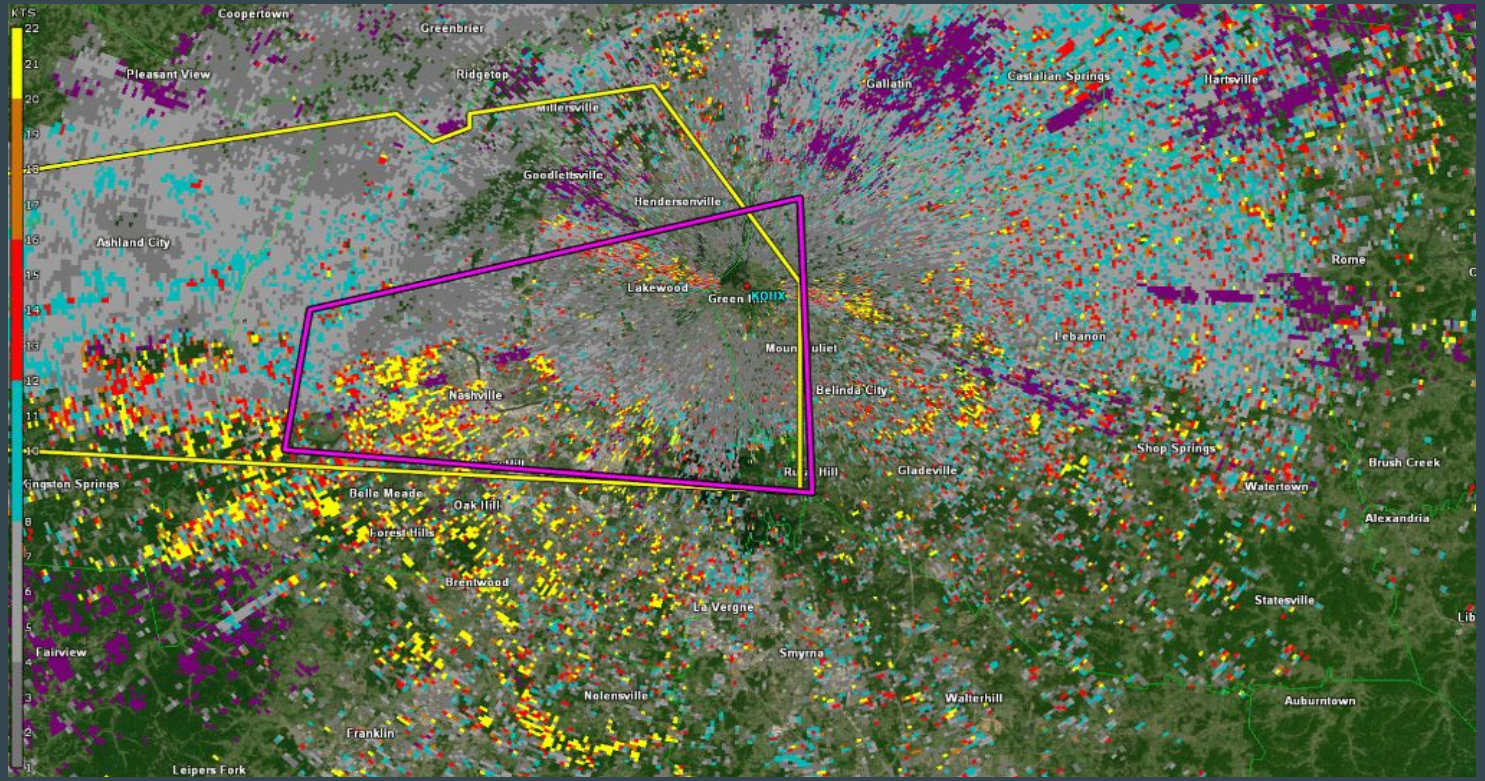

Spectrum width - March 3, 2020

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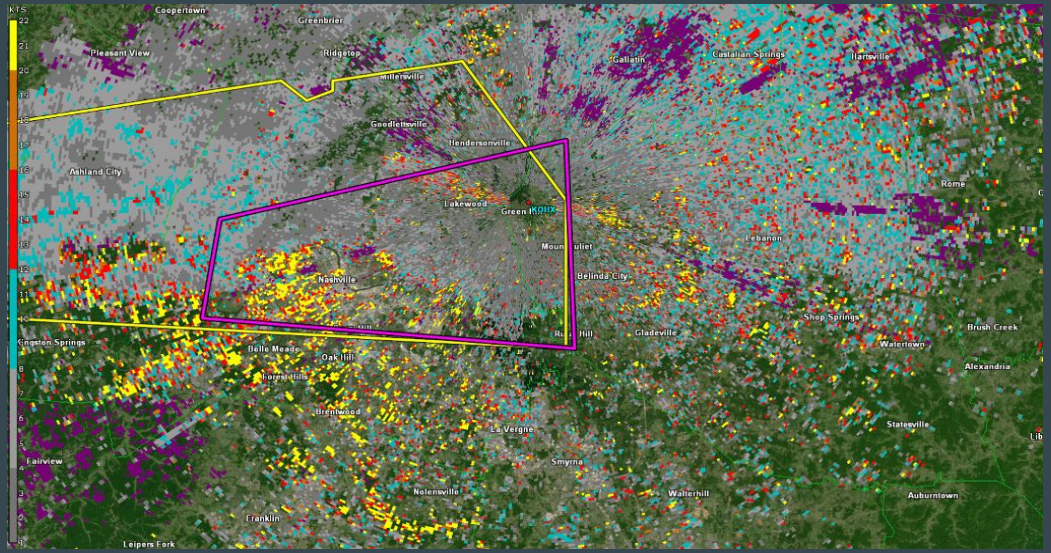
Spectrum Width (SW)

- Detects order/disorder in radar velocities
  - Measured in knots (kts)
- Helps to identify turbulence/wind shear (i.e. gust fronts, center of greatest rotation)
- Higher values = turbulent
- Lower values = less turbulent

**Need to enough targets for accurate reading*



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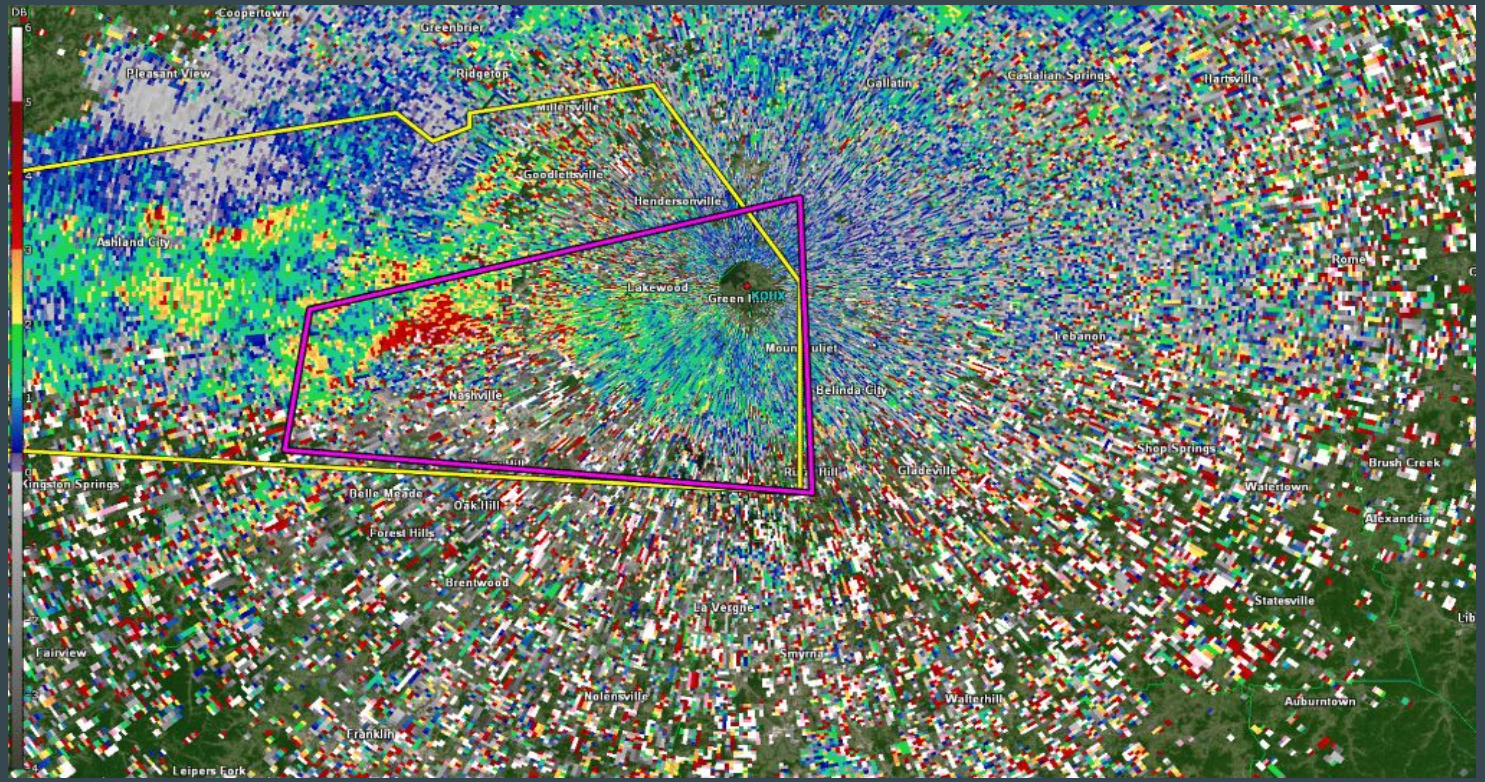

Differential reflectivity - March 3, 2020

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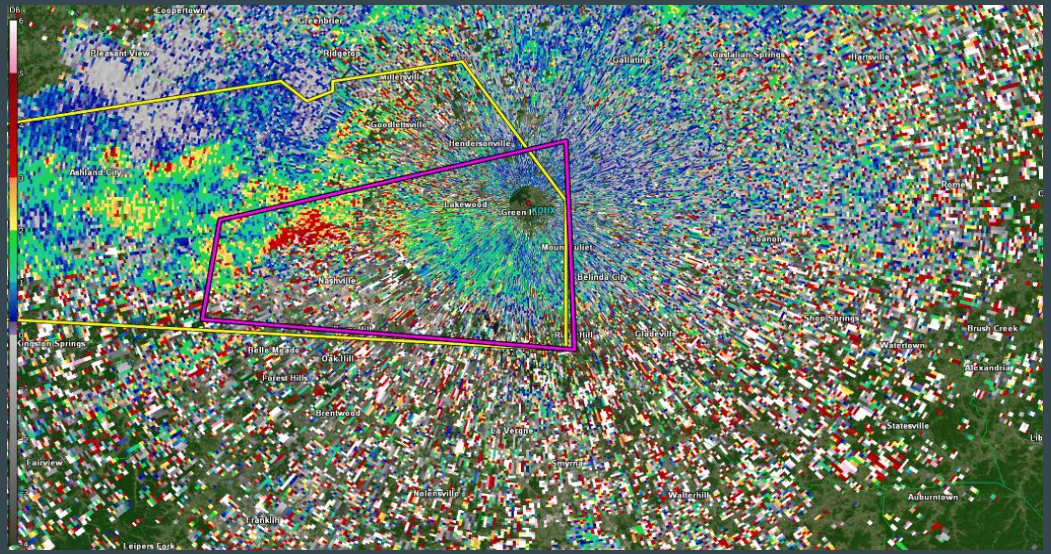
Differential Reflectivity (ZDR)

- Difference in horizontal and vertical reflectivity
  - Measured in dBZ
- Near 0 dBZ: spherical targets
- > 0 dBZ: horizontally-oriented targets
- < 0 dBZ: vertically-oriented targets

**Need to enough targets for accurate reading*



~ 0 dBZ

> 0 dBZ

< 0 dBZ

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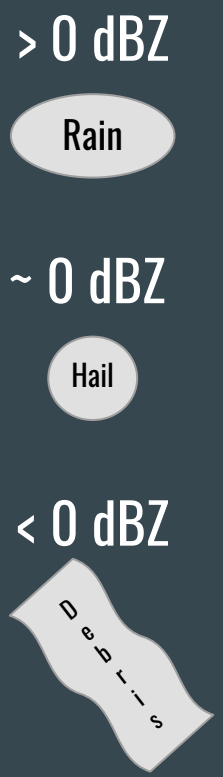
Differential Reflectivity (ZDR)

- Raindrops
  - The larger the drop, the more horizontal/oblate its shape
  - Larger drops = higher ZDR

- Hail
  - Tumbles as it falls, making it appear spherical
  - ZDR values near zero

- Debris
  - Does not have preferred orientation
  - Values near or slightly below zero on ZDR



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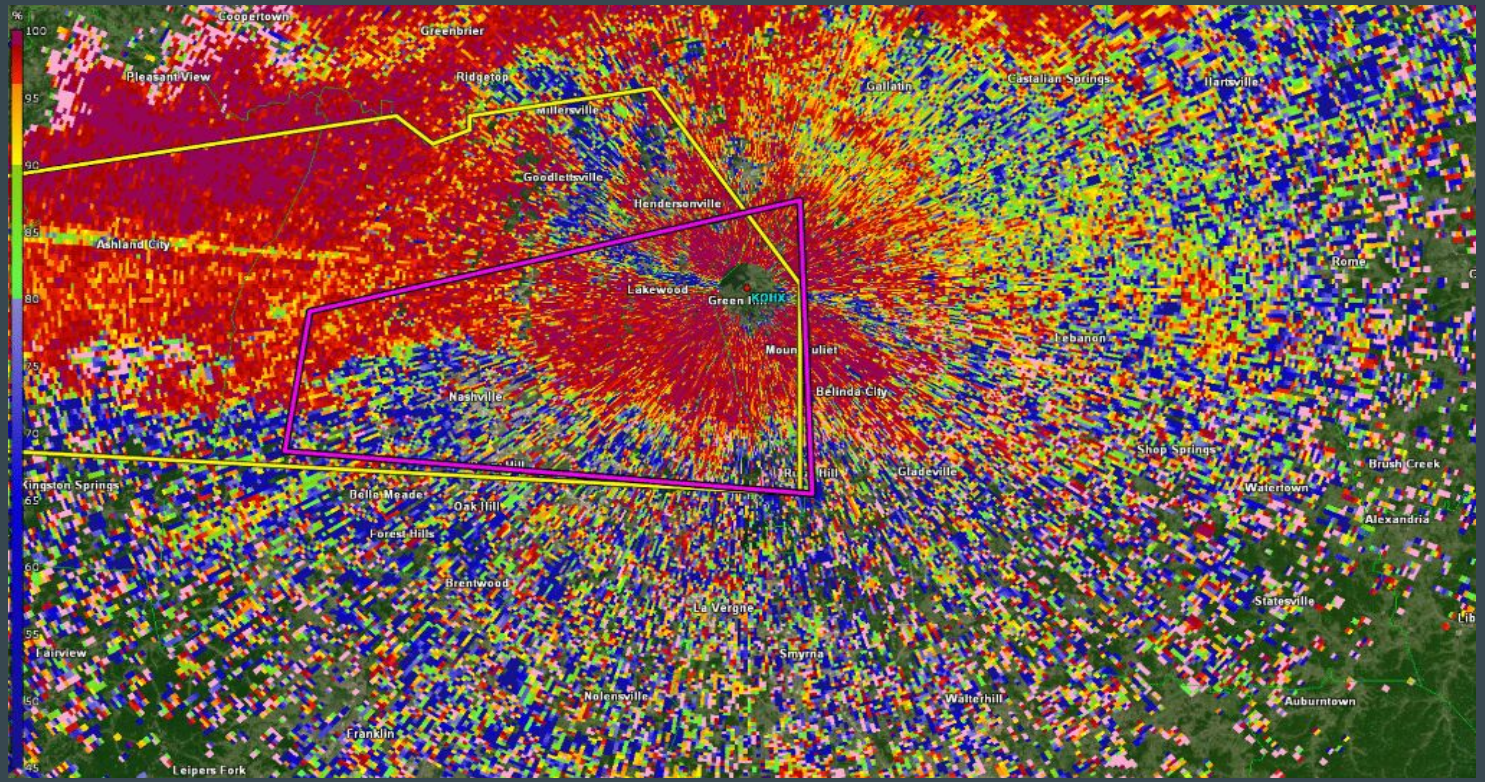

Correlation coefficient - March 3, 2020

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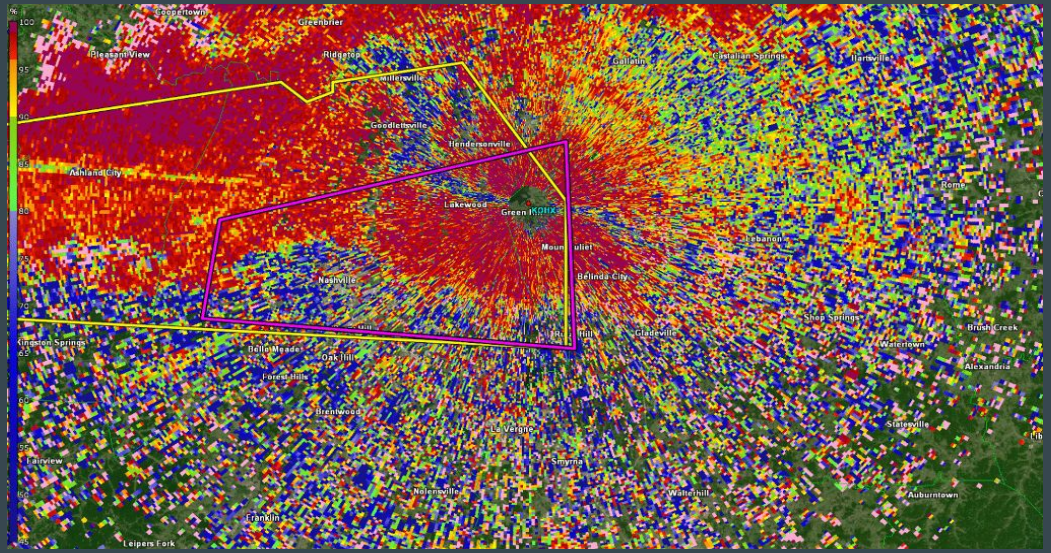
Correlation Coefficient (CC)

- Helps to detect similarities or differences in target shapes
- Higher values = similar targets
  - Rain and some snow
- Lower values = varying targets
  - Wet ice/snow or non-meteorological targets such as debris
  - Can also help detect a melting layer

**Need to enough targets for accurate reading*



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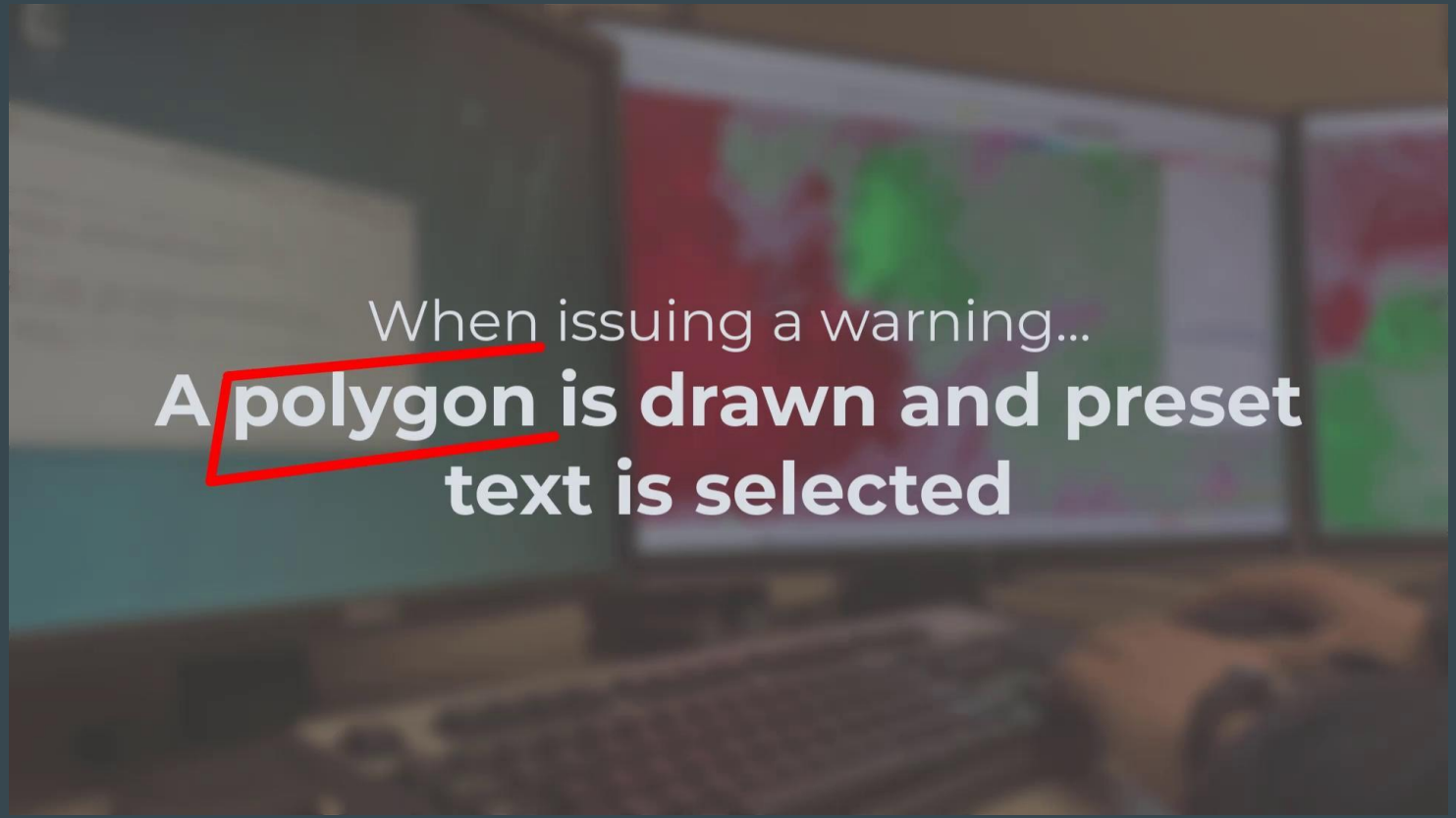

Applying radar analysis to real-life scenarios

Real-life scenario

Radar operator on March 3, 2020

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Rules

- Select from these options:
  - Severe thunderstorm warning (60+ mph wind, quarter size hail or larger)
  - Tornado warning (potential for tornado or tornado in progress)
  - No warning (includes early cancellation)

Severe Thunderstorm Warning

Tornado Warning

No Warning

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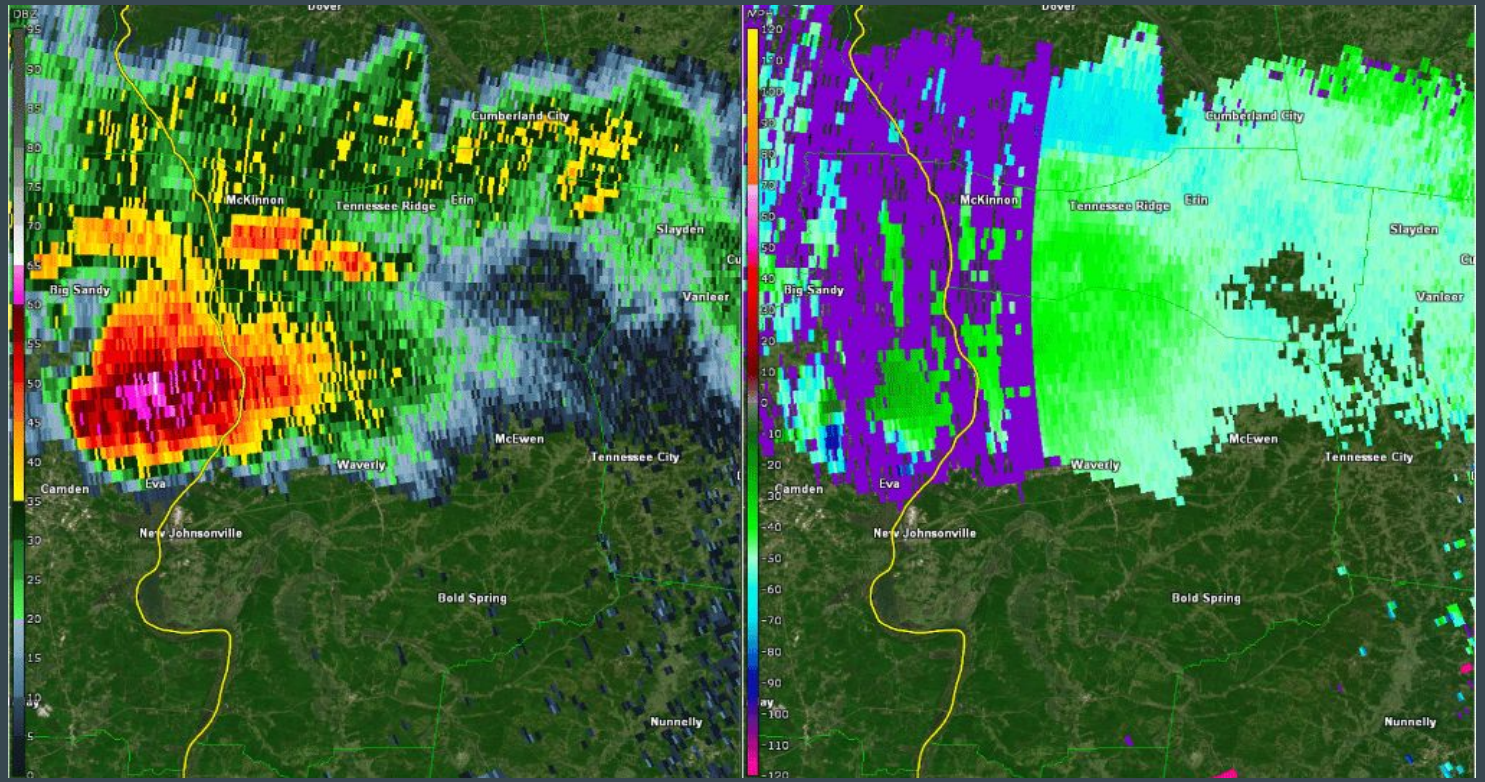

Houston, Humphreys, Dickson - 11:12 PM to 11:54 PM

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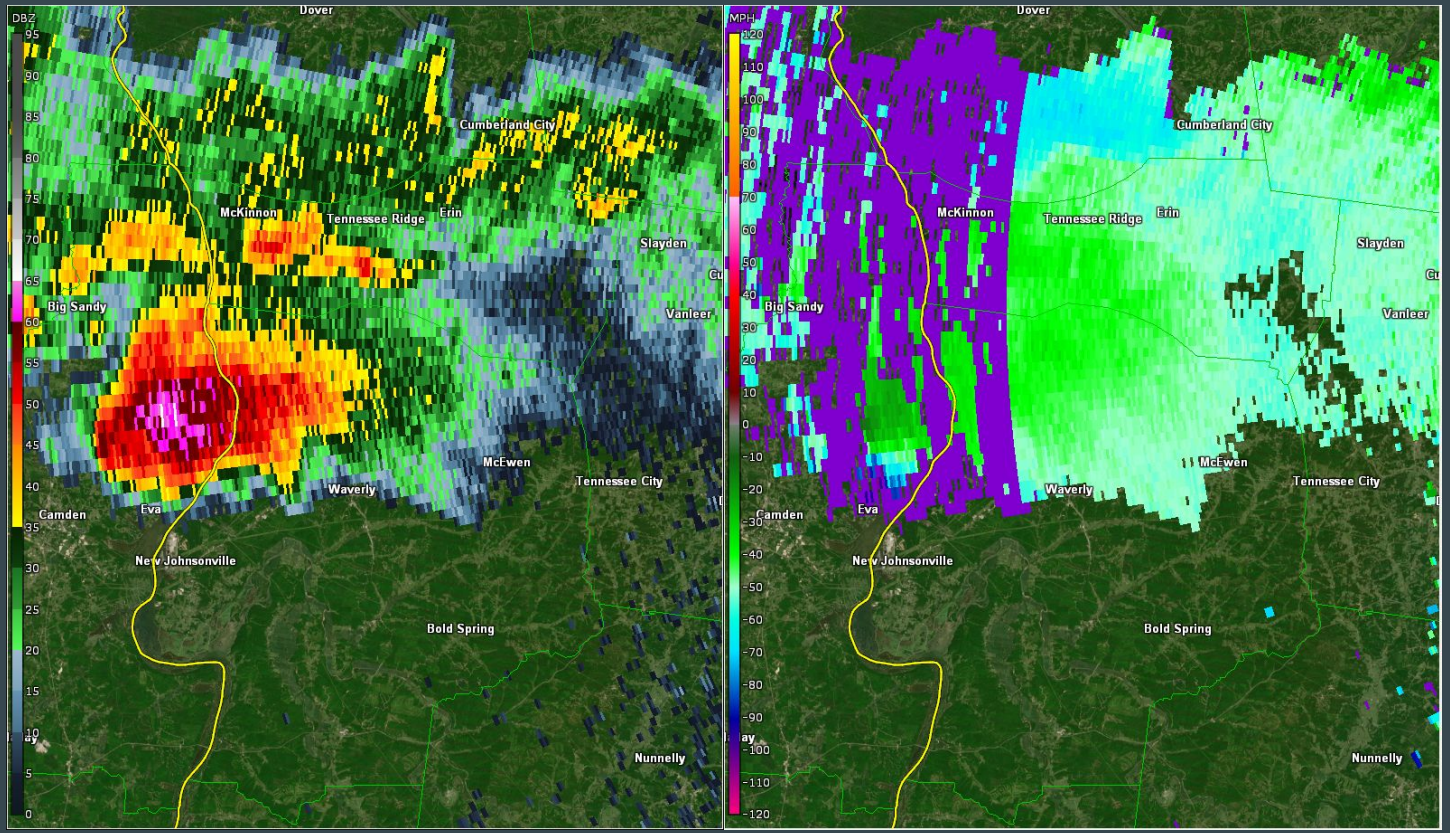

CHOOSE:

Severe Thunderstorm Warning

Tornado Warning

No Warning

11:14 PM - Warning or no warning?

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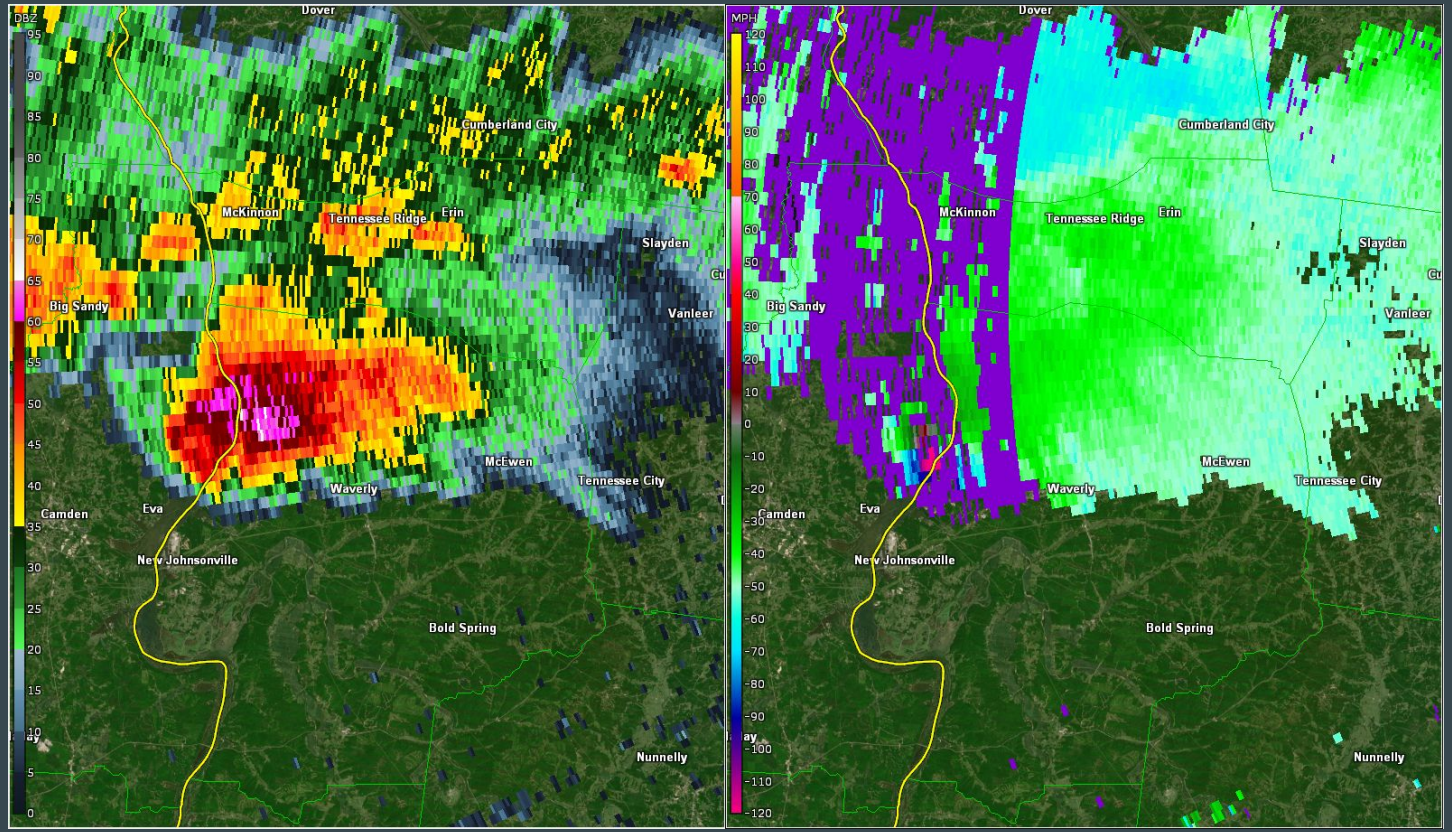

CHOOSE:

Severe Thunderstorm Warning

Tornado Warning

No Warning

11:20 PM - Warning or no warning?

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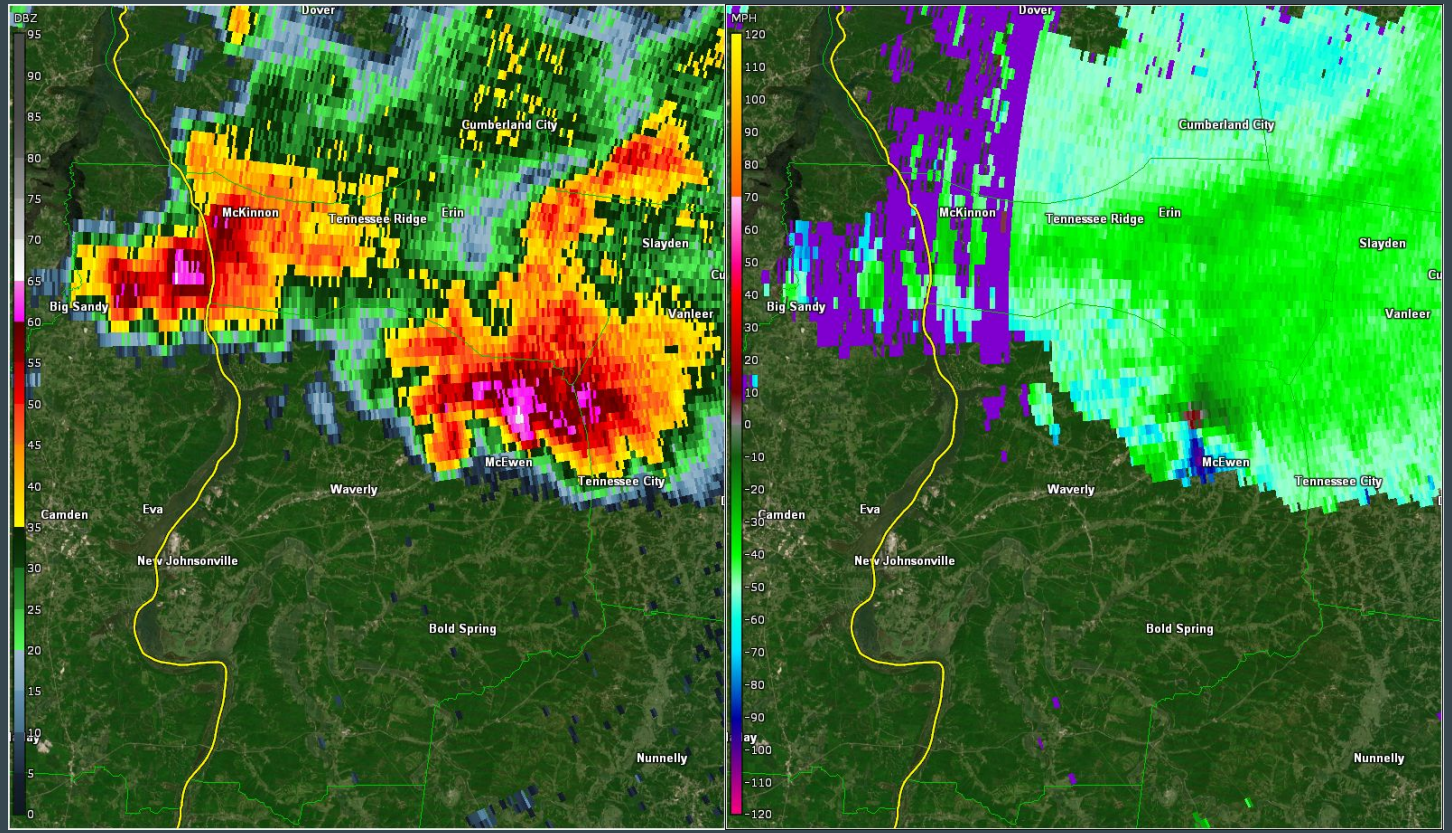

CHOOSE:

Severe Thunderstorm Warning

Tornado Warning

No Warning

11:39 PM - Warning or no warning?

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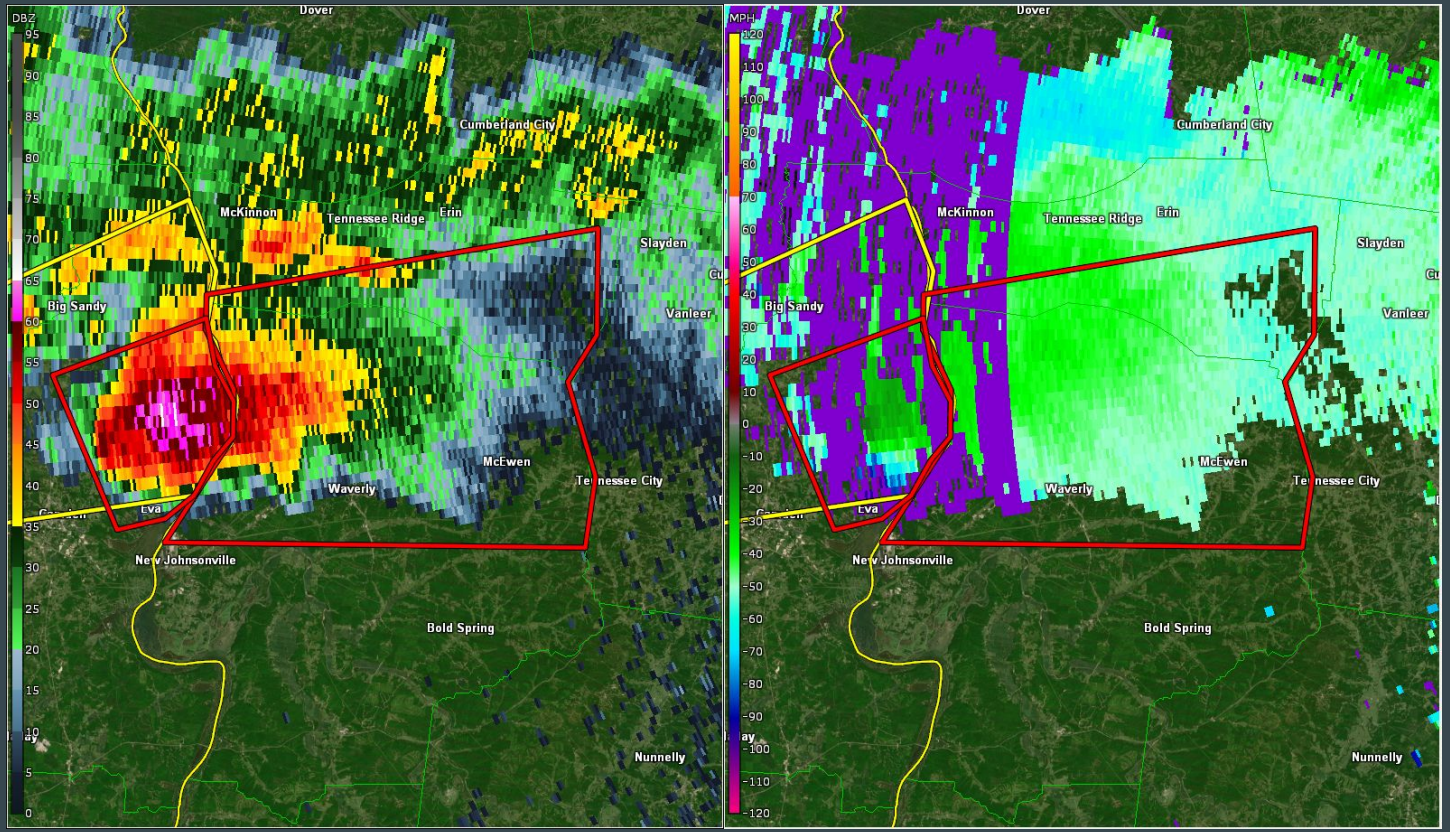
Results

Check your work...



11:14 PM - Actual warnings

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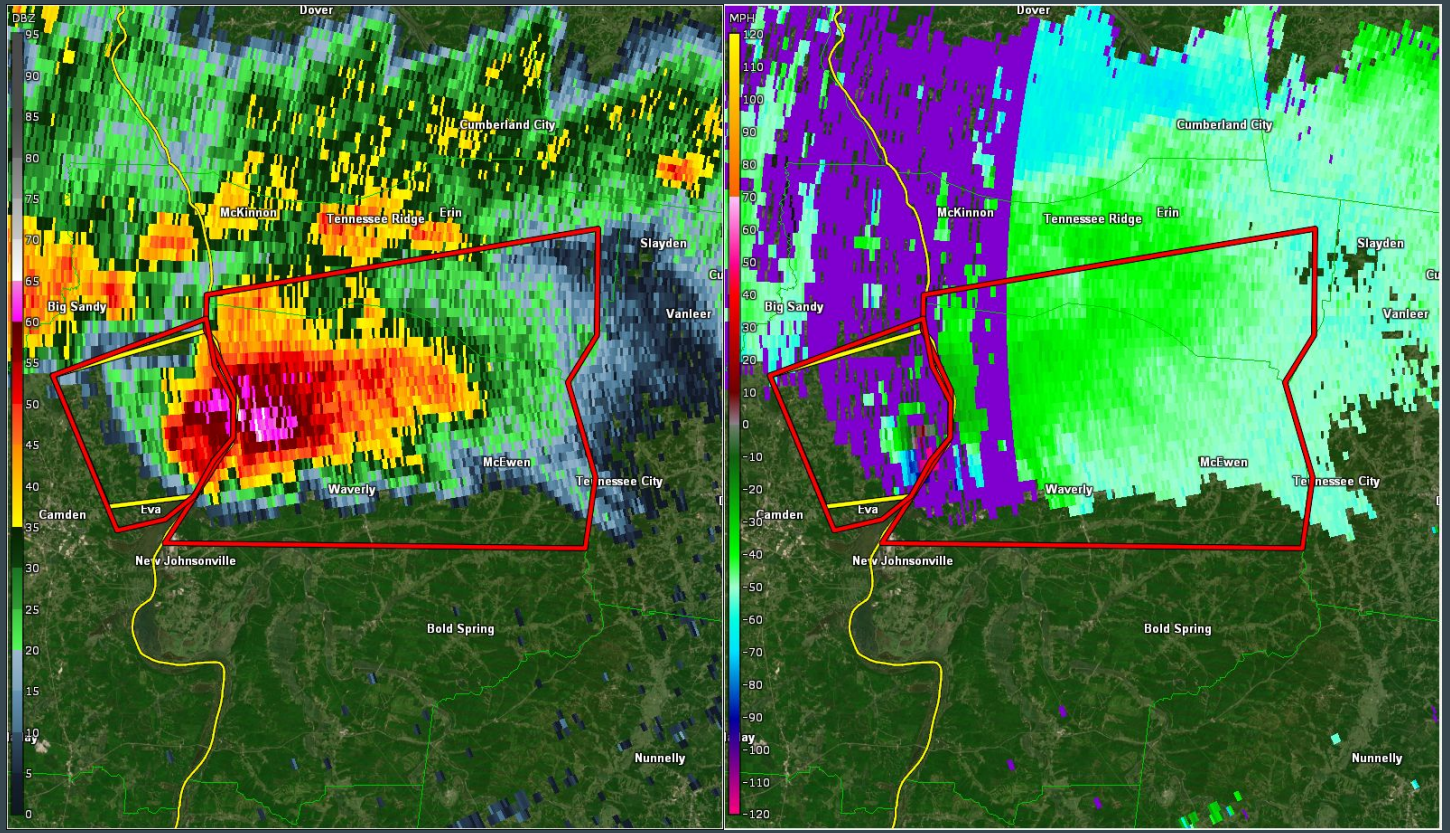

11:20 PM - Actual warnings

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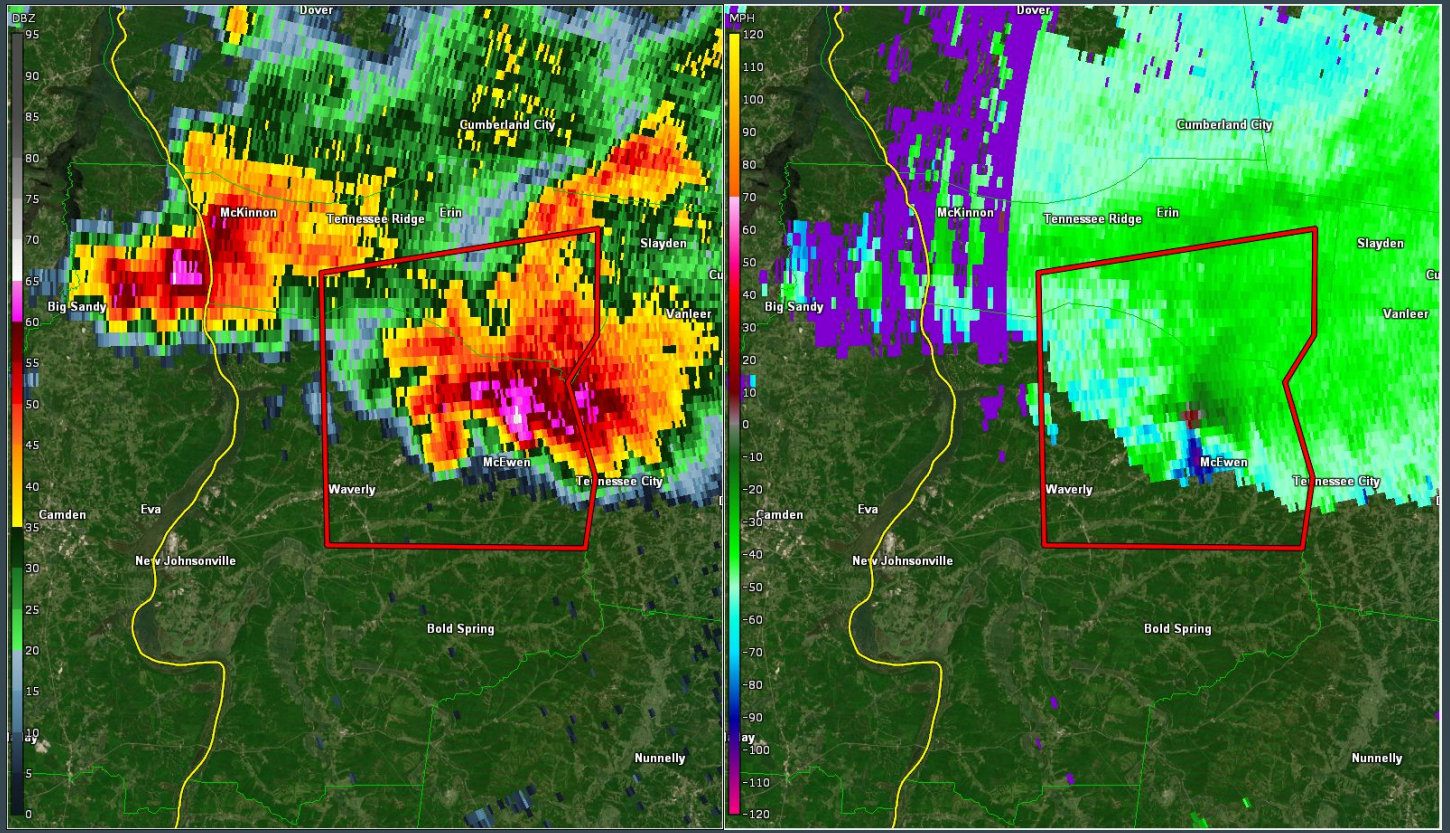

11:39 PM - Actual warnings

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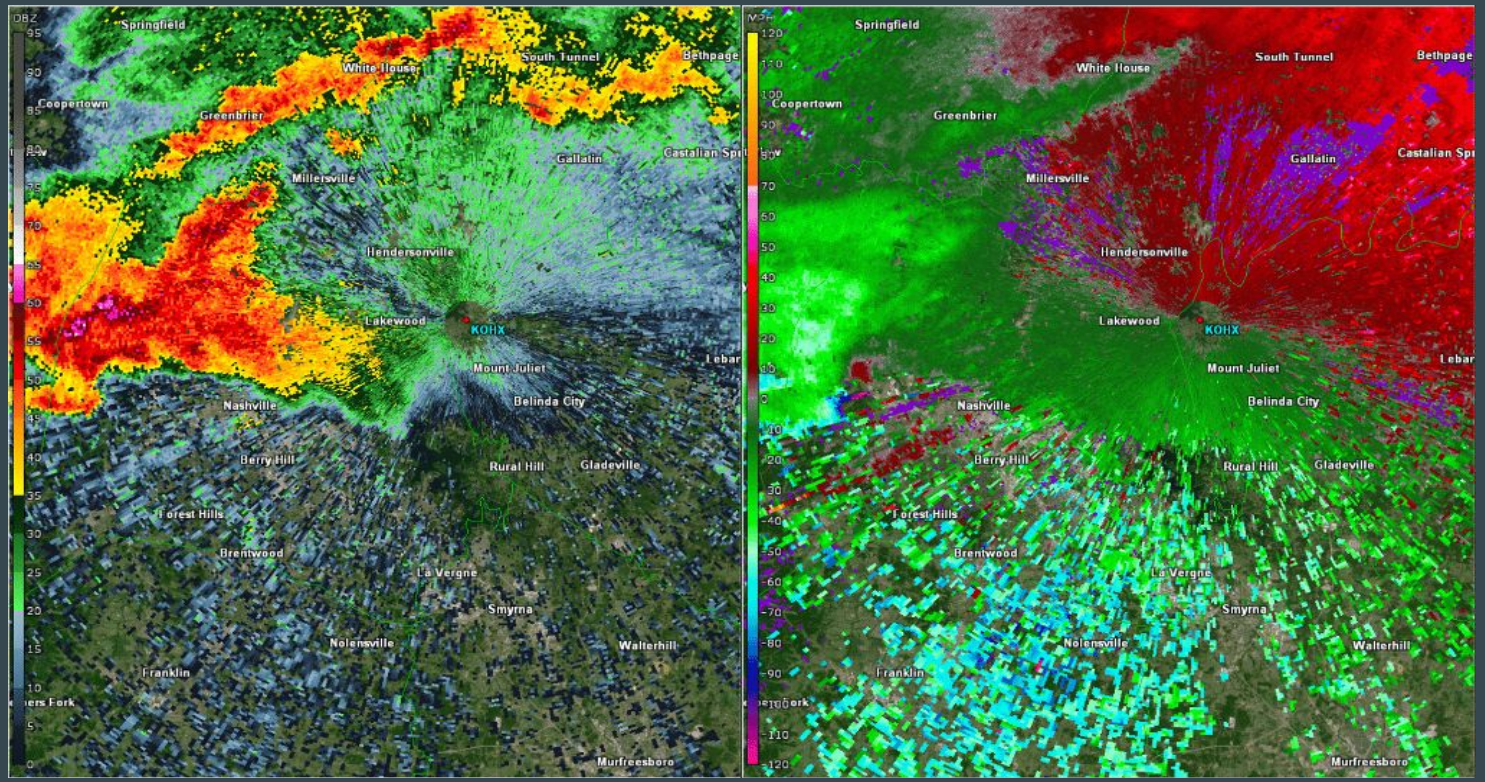
Fast Forward



Davidson, Sumner, Wilson - 12:32 AM to 1:12 AM

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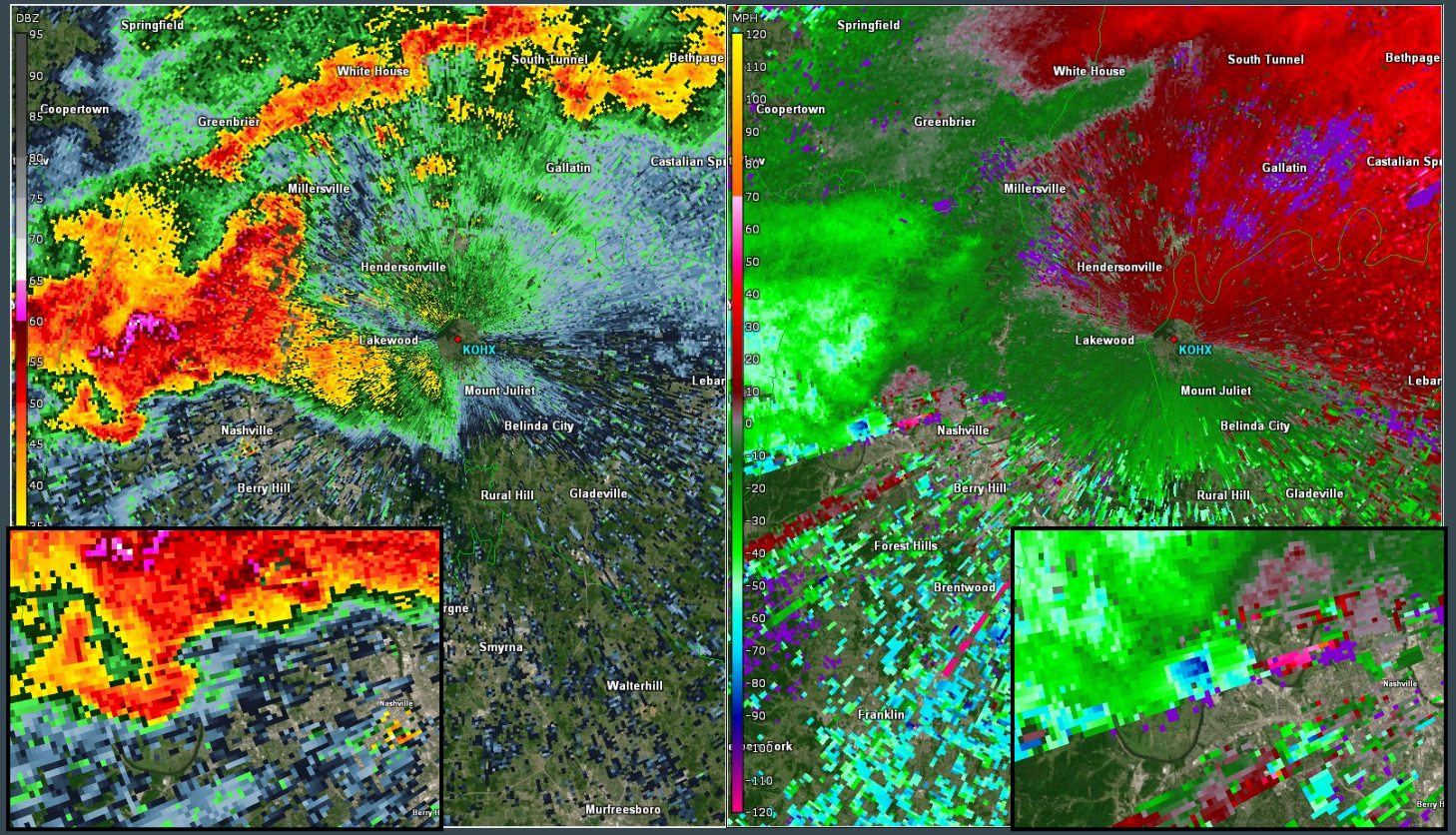

CHOOSE:

Severe Thunderstorm Warning

Tornado Warning

No Warning

12:35 AM - Warning or no warning?

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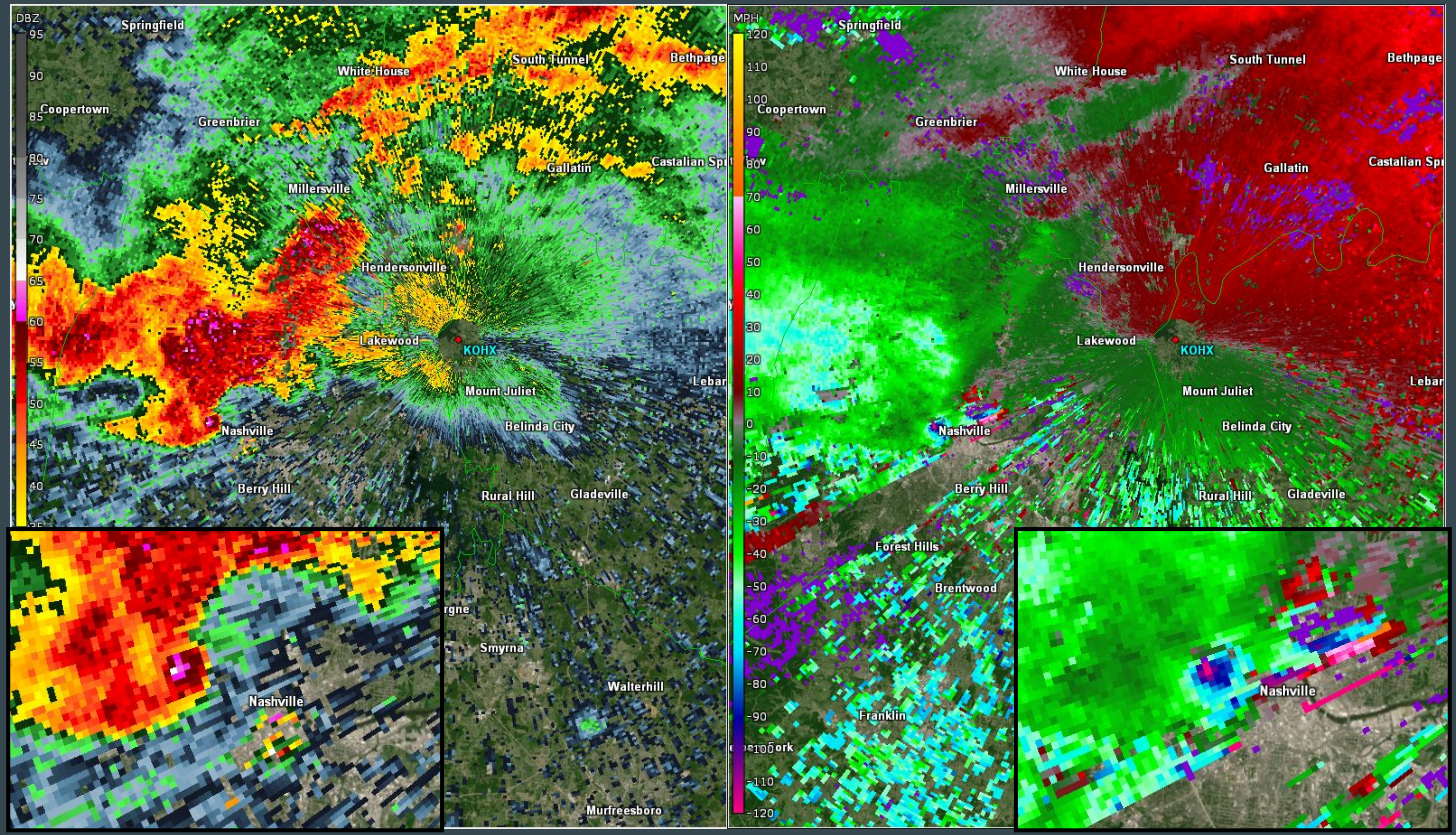

CHOOSE:

Severe Thunderstorm Warning

Tornado Warning

No Warning

12:40 AM - Warning or no warning?

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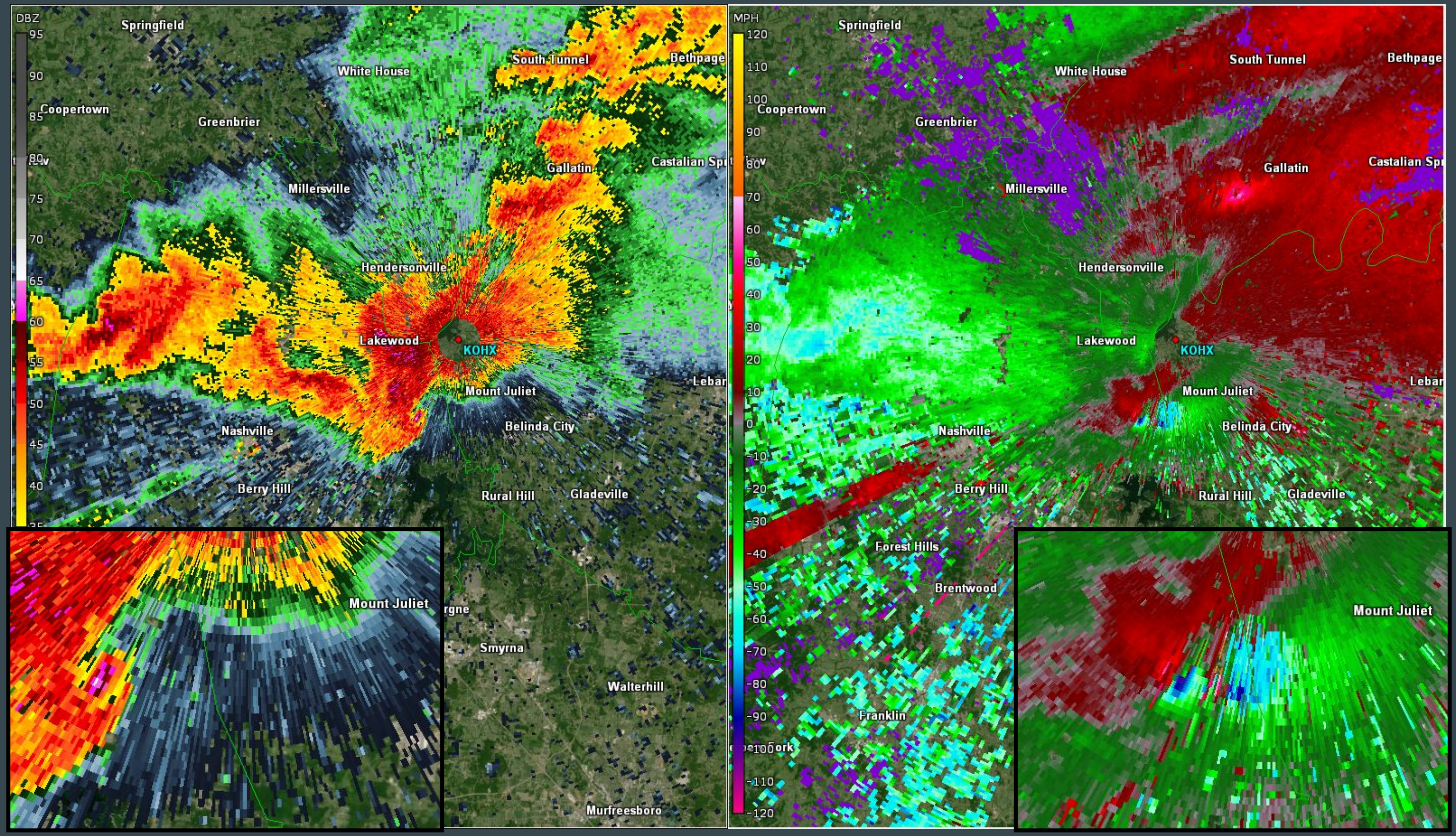

CHOOSE:

Severe Thunderstorm Warning

Tornado Warning

No Warning

12:52 AM - Warning or no warning?

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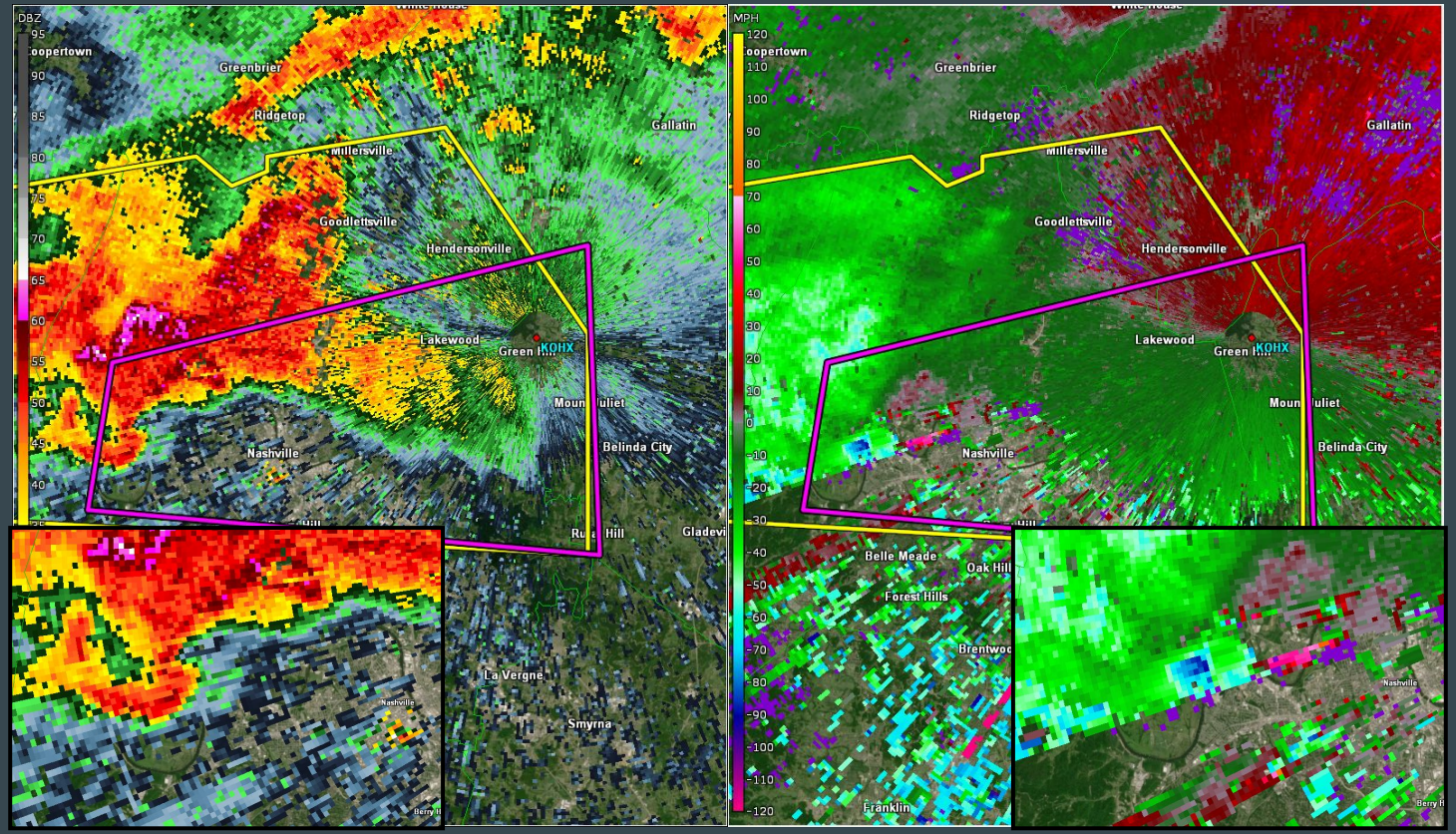
Results

Check your work...



12:35 AM - Actual warnings

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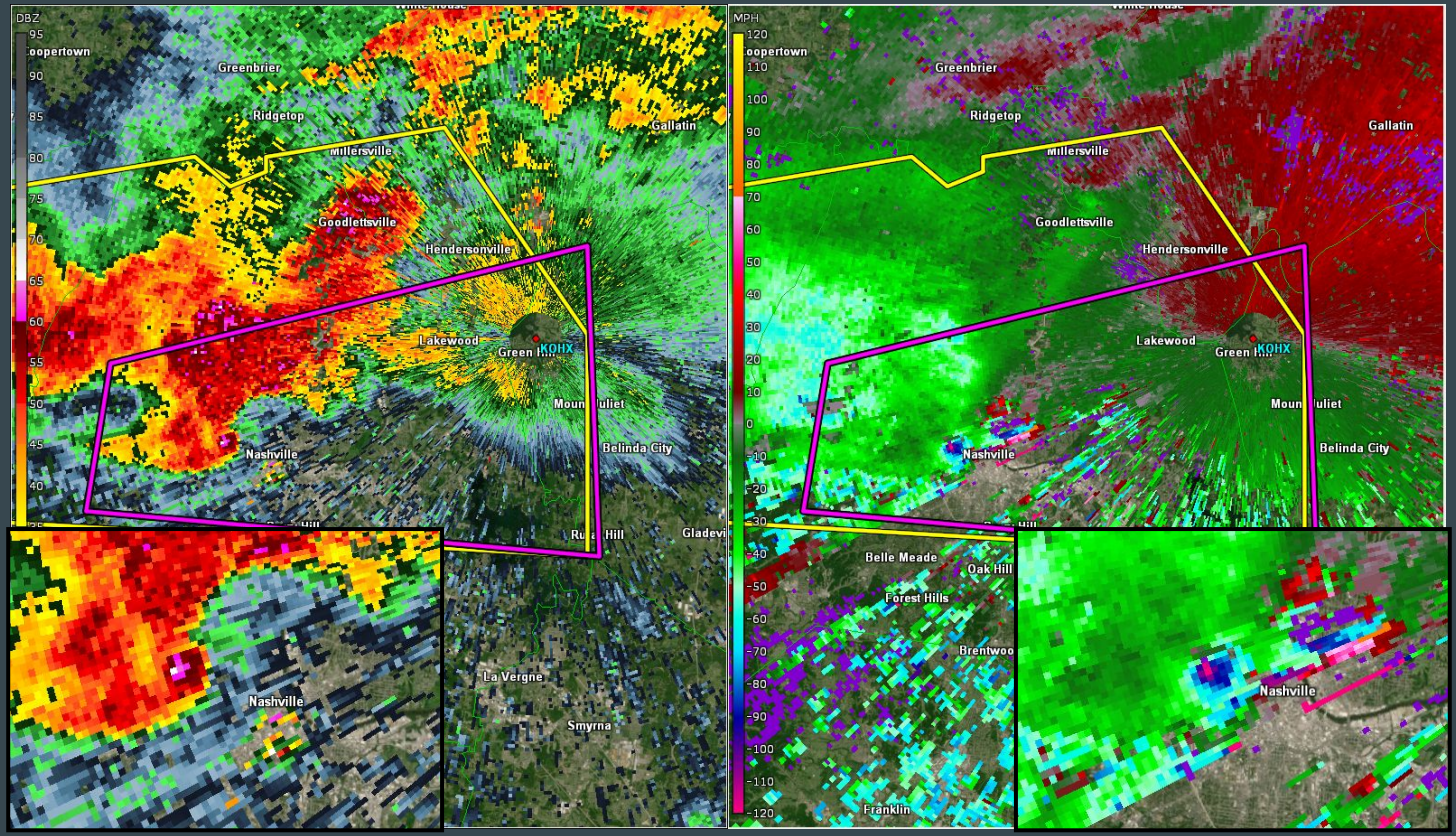
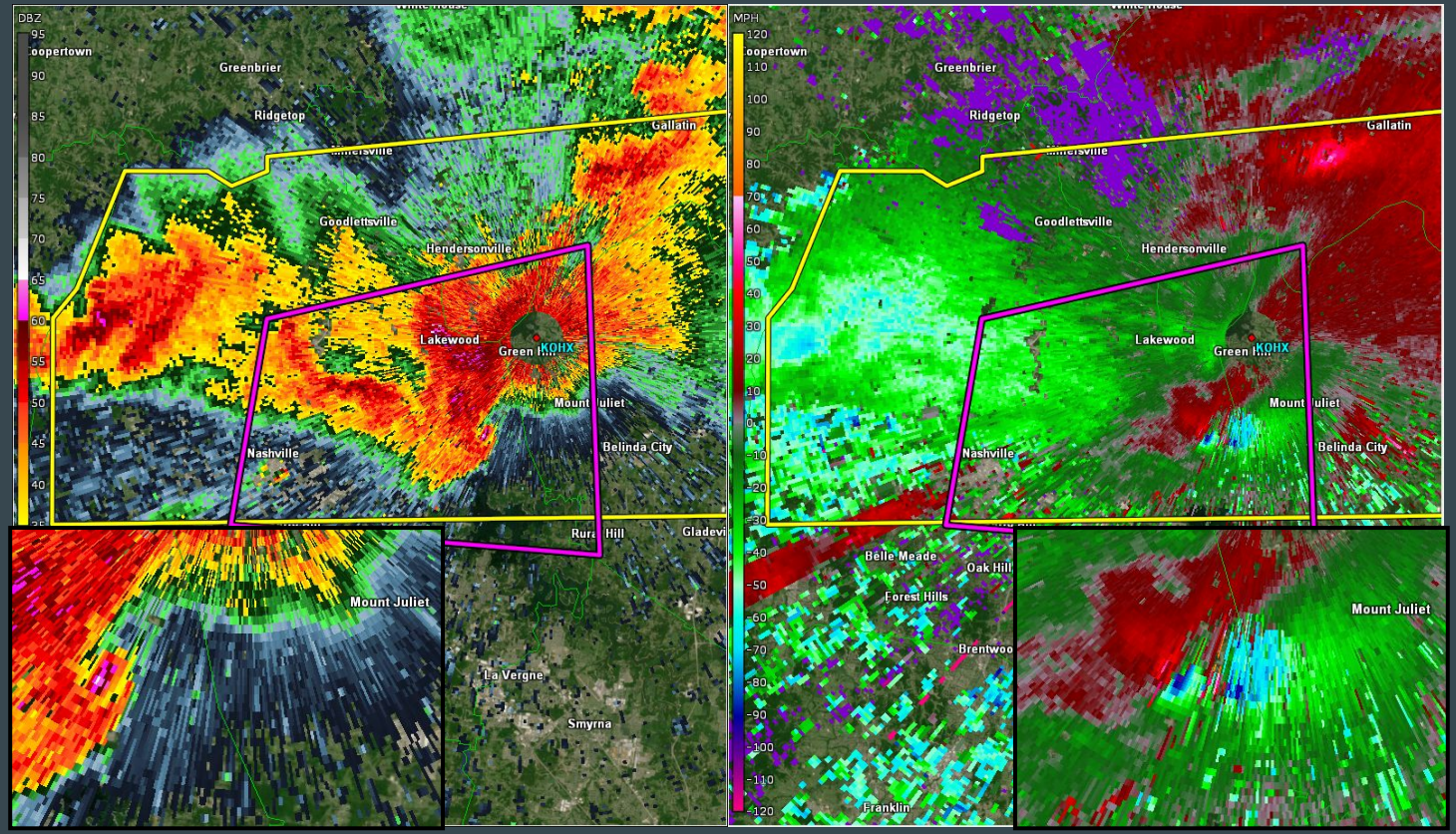


12:40 AM - Actual warnings

NWS Nashville, TN



12:52 AM - Actual warnings

NWS Nashville, TN

More information

For more on the March 2-3, 2020 tornadoes,
visit weather.gov/ohx/20200303.


Lowest to highest elevation
19.5°
15.6°
12.5°
10.0°
8.0°
6.4°
5.1°
4.0°
3.1°
2.4°
1.8°
1.3°
0.9°
0.5°
Remember...radar images are available for many heights in the atmosphere!
NWS Nashville, TN
NATIONAL WEATHER SERVICE

Next class:

Wednesday, April 15th

Observations in 3D: METARs and Upper Air Patterns

Questions?

brendan.schaper@noaa.gov

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